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THE STATUS OF INNOVATIVE TECHNOLOGIES WITHIN THE AUTOMOTIVE INDUSTRY

HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDRED FOURTEENTH CONGRESS

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THE STATUS OF INNOVATIVE TECHNOLOGIES WITHIN THE AUTOMOTIVE INDUSTRY

THURSDAY, JANUARY 21, 2016

U.S. SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES
Washington, DC.

The Committee met, pursuant to notice, at 9:49 a.m. in Room SD–366, Dirksen Senate Office Building, Hon. Lisa Murkowski, Chairman of the Committee, presiding.

OPENING STATEMENT OF HON. LISA MURKOWSKI, U.S. SENATOR FROM ALASKA

The CHAIRMAN. Good morning. We will call to order the Senate Energy and Natural Resources Committee.

This morning we have a hearing on the status of innovative technologies within the automotive industry. The good news for me is I do not have to drive a lot here in Washington, DC, but I know there were a lot of people out on the roads yesterday. They were wondering what the new advances are in automotive technology and industry and how they were going to handle the snow.

We timed this hearing deliberately not just to occur with when we are starting with our bipartisan energy bill, which we are looking to take up at the first of next week on the Senate floor, but we are also here this morning because the Washington Auto Show is commencing. That show kicks off tomorrow. While there is no substitute for going in person, we do have the CEO of the Alliance of Automobile Manufacturers here, Mr. Bainwol. He is here to share his thoughts. So welcome to the Committee this morning.

It is not just the auto show that makes this hearing timely. Auto sales in the U.S. hit an all-time high in 2015 with 17.5 million cars and trucks sold. This banner year was spurred in part by low gas prices. As we heard earlier this week, those prices are projected to remain low throughout the year. Vehicle sales have also been boosted by the tremendous innovation taking place in the auto industry right now, and I think that is a story that deserves more attention.

We have seen dozens of alternative fuel models emerge from electric vehicles like the Tesla Model S to the fuel cell-powered Toyota Mirai to a Ford F–150 that can run on compressed natural gas and propane. At the same time, we have seen exciting developments in everything from safety technology to self-driving cars which may offer their own energy and environmental benefits.

I see today's hearing as an opportunity for us to learn more about significant innovation taking place within the auto industry,

particularly as it relates to alternative fuels and lightweight materials which are at the heart of the Department of Energy's research activities and of this Committee's jurisdiction.

This is a look down the road, if you will. It is a chance for us to hear about the technologies that are emerging, to gauge how they might affect our energy and mineral needs and to understand the challenges that need to be overcome.

This hearing is also a chance for us to recognize that the auto industry is facing heavy regulations right now, particularly when it comes to fuel efficiency. While those particular regulations are not within this Committee's jurisdiction, they do have an impact on our nation's fuel consumption and are worth monitoring as we modernize our energy policies.

Another goal for this hearing is to examine whether Federal programs meant to support innovation are working as intended and whether they are properly oriented to help our auto industry innovate, compete and thrive.

That brings us to the work that the DOE is doing through its Vehicle Technologies Office and at the national labs. I have consistently advocated technology neutral policies for the automotive sector instead of picking one favorite technology and plowing most or all of our limited Federal research dollars into it. I am convinced that the better path is to support research in a wider range of possible winners and to let the markets and the consumers determine which is best.

Here in this Committee I think we are on a good track. As a result of our commitment to work together, our bipartisan energy bill includes several provisions to boost innovation within the automotive industry, including a modified version of the Vehicle Innovation Act which was sponsored by Senators Peters, Alexander, and Stabenow. It will provide the Department of Energy with a structured authority and clear direction for its research mission.

Our energy bill is bipartisan. We worked hard to make sure of that, and I think we can make sure that our vehicle innovation policies are bipartisan too.

I am looking forward to what the witnesses will have to offer this morning.

We will turn to Senator Cantwell.

We do have a vote scheduled at 10:30 this morning and I know that the panel needs to leave by 11:30, so we will be expeditious here this morning.

Senator Cantwell?

STATEMENT OF HON. MARIA CANTWELL, U.S. SENATOR FROM WASHINGTON

Senator CANTWELL. Thank you, Madam Chairman, for holding this important hearing.

Vehicles affect almost all Americans. Today's hearing is a way to talk about new vehicle technologies, so I am interested in hearing from our panelists about the changes that we are seeing in the transportation sector.

The U.S. auto industry has come back during the last seven years and it sold a record number of vehicles last year, but there is still a lot of work to be done.

American vehicles are still very dependent on oil. In fact, transportation is responsible for 70 percent of U.S. petroleum usage and nearly 30 percent of greenhouse gas emissions. So while we have significantly reduced the use of oil in our electricity generation and home heating, we now need to sharpen our focus on the transportation sector.

This is why the Department of Energy has had a long standing relationship with the automotive industry to develop and deploy new and next generation research. The Vehicle Technologies Office works with light duty automobiles as well as commercial trucks to conduct research to improve fuel efficiency standards and on light weight composites, batteries, and materials. I should just say, as a side note, light weight composites have definitely driven great transformation in the aerospace industry and provided great benefits.

The bipartisan energy legislation we passed out of Committee last year builds on the success in part of work done by members of this Committee. Senators Stabenow, Alexander, and Peters (not on this Committee) authored legislation that reauthorizes the Vehicle Technology Office at the Department of Energy and directs focus on new vehicle technologies. I am looking forward to working with the Department on these key programs and exploring the ways in which these partnerships will help make additional modes of transportation more efficient.

As the price of gas continues to drop, in some areas even below $2, consumers are looking and returning to larger vehicles and SUVs. According to the University of Michigan's Transportation Research Institute, the average fuel economy of all vehicles sold in the U.S. in 2015 were less fuel efficient compared to the vehicles sold in 2014. This is the first time since 2008 that the average fuel economy of cars sold has dropped.

But the oil market can be volatile, and we need to remember this. As we heard from our panel on Tuesday, there will be a correction. So increasing the fuel efficiency of U.S. vehicles is one of the biggest steps we can take to save families more money by reducing the cost and helping to reduce emissions. In addition, there are promising new technologies today in alternative fuels, advanced safety features, and light weight composites. Making the right investments can help bring these to larger scale in the market.

In the State of Washington, the Pacific Northwest National Laboratories (PNNL) has partnered with the industry for decades on technologies for cleaner and more fuel efficient vehicles. Researchers have focused on incorporating more aluminum into auto manufacturing to make lighter vehicles. Again, just to go back to aviation, there is huge fuel efficiency savings in aviation. The customers are very happy with those lighter weight planes and the savings that they get.

So the technology from PNNL is being used in vehicles on the road today including the Cadillac STS and the Chevy Malibu Maxx. In addition, the Pacific Northwest National Lab is working on game changing technology using catalysts to produce fuels from plant matter that could change the future of our nation's energy economy. This is important work to help us diversify our sources

of fuel and hedge against volatile energy markets for the future, but improving efficiency is also brought about by focusing on our freight network. Each year three billion gallons of fuel is wasted due to congestion and businesses across the country pay the price which is estimated at $27 billion a year in added transportation costs. So as our export economy continues to grow and as we produce great products, we have to get them to market so that is why, particularly, the super truck program is very important. I know my colleague from Michigan is here, and she has been a leader on helping on this in order to achieve more fuel efficiency.

Meanwhile electrification of our transportation sector provides important benefits, and an electric vehicle can save a consumer up to $1,200 a year in fuel prices and it could reduce emissions by 48 percent compared to a gasoline-fueled car. The Department of Energy has partnered with industry to help drive down the cost of electric car batteries and improve performance. In 2008 the average battery pack was more than $1,000 per kilowatt. Today it is estimated to be less than $300. This means vehicles can travel further and with better performance.

But we need to continue to ensure that we are focusing on these next generation technologies. There are currently only 900 public fast charging stations and 14 hydrogen refueling stations compared to almost 170,000 gas stations across the United States of America.

I look forward to hearing from the witnesses today. How we can continue to answer that part of this equation? And of course, self-driving cars are an important aspect of the discussion of the future of automobiles, and I look forward to what our witnesses have to say on that.

Secretary Moniz and others have made a fine point to continue the discussion on the public/private partnerships that drive successful innovation efforts. I know this recent mission innovation that the Secretary and others in the private sector, like Bill Gates, are pioneering are an important aspect for us doing our job here in making sure that we continue to have the next generation of technology so the United States can continue to be a leader in manufacturing cars.

Thank you.

The CHAIRMAN. Thank you, Senator Cantwell.

We will now turn to our panel. I would advise that each of you will have five minutes for your oral testimony and your full statements will be included as part of the record, but we would ask you to try to observe that five-minute timeline so that we can get to our questions of you.

We have a very distinguished panel this morning led off by Mr. David Friedman, who is the Principal Deputy Assistant Secretary for the Office of Energy Efficiency and Renewable Energy at the Department of Energy. Thank you for joining us.

We have Mr. Mitch Bainwol, who I just mentioned, who is the President and CEO of the Alliance of Automobile Manufacturers. You are busy this time of year.

Ms. Genevieve Cullen is the President of Electric Drive Transportation Association. Welcome to the Committee.

Dr. Chris Gearhart is the Director of Transportation and Hydrogen Systems Center at the National Renewable Energy Lab. Welcome.

The final member of the panel this morning is Mr. Xavier Mosquet, who is the Senior Partner and Managing Director for the Boston Consulting Group.

So welcome to each of you.

Mr. Friedman, if you would like to lead off, please?

STATEMENT OF DAVID FRIEDMAN, PRINCIPAL DEPUTY ASSISTANT SECRETARY, OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY, U.S. DEPARTMENT OF ENERGY

Mr. FRIEDMAN. Well thank you, Chairman Murkowski, Ranking Member Cantwell and all the members of the Committee, for the opportunity to be able to testify today on behalf of the Department of Energy's Office of Energy Efficiency and Renewable Energy.

If we look at the world today our national imperative is clear. We must win the clean energy race. And when we do that we will capture a significant share of the multi trillion-dollar global clean energy market and the jobs, the energy security and the other opportunities that will be created along the way.

As Principal Deputy Assistant Secretary at the Department of Energy's EERE, I help manage a broad portfolio of solutions comprised of high impact applied research, development and demonstration activities to deliver on our mission through renewable power, energy efficiency and of course, our focus today, sustainable transportation.

As we heard earlier transportation accounts for more than 70 percent of U.S. petroleum usage, about one-fifth of household expenditures and nearly one third of U.S. energy-related carbon emissions. It also remains a significant source of other air pollutants that are harming our children and their grandparents.

Our transportation program focuses on two key solutions to these challenges. First, using less energy to move people and freight. Second, fueling vehicles with cost competitive, domestically produced, alternative fuels with lower greenhouse gas emissions.

Through our work at the National Renewable Energy Lab and with our other national lab partners, private sector partners and other key stakeholders, we've helped deliver significant results through technologies that are on the market today. In fact, each dollar we've invested in heavy duty vehicle combustion technology has delivered about $70 in net benefits for taxpayers, a 70 to 1 ratio.

Our super truck program has shown the potential to cut the fuel use of low haul trucks by one third to one half and some of the air dynamic and tire technologies from that program are already making their way into the market.

Then the batteries from the Chevy Bolt, Volt, Spark, the Cadillac ELR and the Ford Focus plug in electric vehicles all tap into industry licensed technology developed at Argonne National Labs.

EERE backed research has also helped increase fuel cell durability four fold while cutting projected high volume costs in half since 2006.

And thanks, in part to research and memory electrode assembly technology developed at Los Alamos National Labs, two companies today are selling or leasing fuel cell vehicles with another one to enter the market this year and others soon to follow.

Now while we're proud of how far we've come, there's a lot more to do. As President Obama and other world leaders affirmed at the launch of the Mission Innovation Initiative in November, solving our energy and climate challenges will require significantly accelerated development and innovation of new technologies. And while we continue to lead the world on innovation and entrepreneurship, we've historically underinvested in clean energy. In fact, compared to the size of our economies, we invest about one third as much on clean energy research and development as competitors like China and Japan.

As we try to reverse this trend we will continue our electric and heavy duty vehicle work. We will also invest in other important areas like the co-optimization of new fuels and engines to boost efficiency and renewable fuel use through work at NREL and other national labs through cross cutting R and D efforts to develop advanced high strength materials to reduce cost, improve performance and enhance manufacturing processes for automotive use, such as the ongoing work mentioned before at Pacific Northwest National Labs, as well as composites work there and at Oak Ridge National Labs and across the country through our Institute for Advanced Composites Manufacturing Innovation.

Grid modernization is also important to fully integrate plug in electric vehicles and fuel cells into the national grid in a safe, secure, reliable and cost effective manner including critical cyber security work at Idaho National and other laboratories. And research and transportation mobility is also critical in order to identify untapped, system level, energy savings through connected and automated vehicles like those at the Ann Arbor Connected Vehicle Test Program.

With programs like these and support from you and the technologies you'll hear about from NREL and Dr. Gearhart, the Department of Energy will continue to strive innovation within the auto industry and into the vehicles on showroom floors and highways across the United States.

I look forward to working with Congress and very much with this Committee to further advance transportation technologies to create new jobs in industries while saving consumers and businesses money and helping to address our nation's energy and climate challenges.

Thank you very much.

[The prepared statement of Mr. Friedman follows:]

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Statement of

David Friedman

Principal Deputy Assistant Secretary
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Before the

Committee on Energy and Natural Resources
United States Senate

January 21, 2016

Introduction

Chairman Murkowski, Ranking Member Cantwell, and Members of the Committee, thank you for the opportunity to testify today on behalf of the Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) regarding EERE's Sustainable Transportation Portfolio and the status of innovative technologies within the U.S. automotive industry.

As Principal Deputy Assistant Secretary at EERE, I help manage and oversee a broad technology portfolio designed to lead DOE's efforts as the U.S. Government's primary clean energy and energy efficiency technology organization. In order to achieve our mission to create and sustain American leadership in the transition to a global clean energy economy, EERE works with some of the Nation's best innovators and businesses to support high-impact applied research, development, and demonstration (RD&D) activities in the three sectors under our purview: sustainable transportation, renewable power, and energy efficiency. With Congress's support, we utilize extensive science and engineering expertise to implement a range of strategies aimed at reducing U.S. oil use, saving American families and businesses money, creating jobs, and reducing pollution. We work to ensure that the clean energy and energy efficiency technologies of today and tomorrow are invented and manufactured in America.

Today, the United States is faced with a national imperative to address the enormous challenge presented by climate change and to seize upon the multi-trillion dollar economic opportunity that a transition to a global clean energy economy will provide.

While the United States has world-class innovation capacity and a unique culture of entrepreneurship, there has historically been significant under-investment in many of clean energy's most promising and important technologies. As these technologies have advanced, market barriers have become a more significant and visible limitation to the speed of deployment. Our sense of urgency is further increased as we see the rest of the world investing billions of dollars in clean tech R&D and deployment while the impacts of climate change are becoming more apparent in our daily lives.

Our national imperative is clear: win the clean energy race. This would ensure that the United States captures a significant and growing share of the multi-trillion dollar global clean energy market and the jobs, energy security and other opportunities that will be created along the way.

U.S. petroleum use creates significant economic, security, environmental, and public health challenges. Currently, transportation accounts for more than 70% of U.S. petroleum usage with on-road vehicles currently responsible for 85% of this amount. The U.S. transportation sector accounts for approximately one-third of U.S. energy-related carbon pollution and, despite recent progress, remains a significant source of other air pollutants that cause asthma, lung disease, and other health problems among the most vulnerable of our population.[1] The average

[1] Transportation sector pollutants account for more than half of all carbon monoxide and NOx emissions, almost a quarter of all volatile organic compounds, and two to six percent of particulate matter emissions. See Transportation Energy Data Book 34th Edition, ORNL, 2015. http://cta.ornl.gov/data/tedb34/Edition34_Full_Doc.pdf.

U.S. household spends nearly one-fifth of its total family expenditures on transportation, making it the second-most expensive spending category after housing. In addition, over the last 10 years, U.S. regular conventional retail gasoline prices have fluctuated from below $1.50 to over $4,[2] affecting annual household budgets by as much as $1,500 per average passenger car.[3]

Sustainable transportation is an important component of the Administration's push to spark innovation in renewable and energy efficient technologies and the Climate Action Plan's goals to reduce carbon emissions.

I am pleased to be here today and look forward to working with Congress, and this Committee in particular, to talk about how we can advance sustainable transportation technologies as a tool to help address our Nation's energy challenges. My statement today will discuss the progress made under DOE's Sustainable Transportation programs, how the impact of our work has been transformative and can be seen in the vehicles on showroom floors across the United States today, and to highlight research and development activities that will spur the next generation of innovative technologies in the transportation sector.

EERE's Sustainable Transportation Portfolio Overview

Through its sustainable transportation portfolio, EERE supports research, development, and demonstration work and other efforts to address market barriers for a variety of promising sustainable transportation technologies. Broadly, the Vehicle, Bioenergy, and Fuel Cell Technologies Offices support two key parallel solution pathways: (1) using less energy to move people and freight and (2) replacing conventional fuels with cost-competitive, domestically produced, sustainable alternative fuels with lower greenhouse gas emissions. Because most petroleum use in the transportation sector occurs in personal vehicles and heavy trucks, EERE's portfolio emphasizes transportation technologies in these areas.

EERE advances the development of next-generation technologies to improve plug-in electric, fuel cell electric and other alternative-fuel vehicles, advanced combustion engine and vehicle efficiency, and produce low-carbon domestic transportation fuels. These efforts are heavily informed by partnerships with National Laboratories, the private sector and other key stakeholders. EERE's transportation programs have longstanding relationships with industry in the form of partnerships focused on pre-competitive research and development (R&D).

For example, the U.S. DRIVE (Driving Research and Innovation for Vehicle efficiency and Energy sustainability) partnership brings together DOE and its National Laboratories and the automotive, energy, and electric utility industries with a focus on light-duty vehicles and related energy infrastructure. Similarly, the 21st Century Truck Partnership brings together DOE, national laboratories, and other Federal agencies (Department of Defense, Environmental Protection Agency, and the Department of Transportation) with industry partners including medium- and heavy-truck manufacturers and suppliers. The 21st Century Truck Partnership's overall vision is for our nation's trucks and buses to safely and cost-effectively move larger

[2] Energy Information Administration, Gasoline and Diesel Fuel Update, historical tables, https://www.eia.gov/petroleum/gasdiesel/

[3] U.S. Department of Labor, Consumer Expenditure Survey 2013, Table 1202, Washington, DC, 2014, and multiyear survey tables. http://www.bls.gov/cex/

volumes of freight and greater numbers of passengers while emitting little or no pollution and dramatically reducing the dependence on oil. These partnerships provide a framework for frequent and regular interaction among technical experts to accelerate R&D progress, avoid duplication between government and industry, and ensure that EERE's RD&D programs remain focused on high-risk barriers to technology commercialization, and ultimately, that technologies progress from the lab and into the manufacturing lines.

DOE is also a member of H2USA, a public-private partnership to address the key challenge of a widespread hydrogen infrastructure. As part of this partnership, EERE established the H2FIRST (Hydrogen Fueling Infrastructure Research and Station Technology) project, which is a collaboration between the National Renewable Energy Laboratory and Sandia National Laboratories and addresses infrastructure challenges such as metering, fueling protocol validation and developing approaches to reduce station cost, permitting times and station siting. All of these partnerships better enable EERE to continue to drive innovation, technology development and market adoption.

Accomplishments and Impacts on the U.S. Market Today

EERE-supported technological accomplishments continue to help U.S. families and businesses by reducing fuel costs, providing a range of vehicle and fuel choices, and by lowering greenhouse gas emissions and oil use. Over the past five years, we have witnessed new technologies enter the U.S. market for passenger and commercial vehicles that are improving fuel efficiency and offering new options for consumers and businesses. EERE has played a critical role in driving down the cost and improving the performance of these technologies to bring them into the market. Let me highlight a few innovations that are having a direct impact on the automotive industry today.

Reduced fuel costs for heavy duty trucks to help businesses save money. DOE's Vehicle Technologies Office (VTO) initiated the SuperTruck program in 2009 with the goal of increasing the freight efficiency of long-haul trucks by 50% in 2015 compared to a 2009 baseline. The technologies that enable these significant fuel efficiency improvements are actually a suite of innovations that, in aggregate, result in big impacts. Modifications to the trailer that improve aerodynamics and low rolling resistance tires can be easily paired with existing trucks to achieve up to 27% fuel savings.[4] One incredibly simple but effective example is the "skirts" that are now often observed below the side and between the wheels of the trailer to reduce drag. Prototype designs for new engine platforms are emerging from the SuperTruck program, and these are targeted to be up to 15% more efficient than 2009 models.[5] Engine technologies will include advanced powertrain electronics that will deliver gains in fuel economy through optimization and precise control of combustion, fuel injection, air handling, reductions in

[4] Salari, Kambiz, Lawrence Livermore National Laboratory, *DOE's Effort to Improve Heavy Vehicle Fuel Efficiency through Improve Aerodynamics.* VTO Annual Merit Review Presentation. June 2014. http://energy.gov/sites/prod/files/2014/07/f17/vss006_salari_2014_o.pdf.

[5] Gibble, John. Volvo. *Powertrain Technologies for Efficiency Improvement.* 2015 Vehicle Technologies Annual Merit Review presentation. June 2015. http://www.energy.gov/eere/vehicles/downloads/vehicle-technologies-office-merit-review-2015-volvo-supertruck-powertrain.

friction and devices that recover energy losses. SuperTruck partners have already introduced other technologies developed and demonstrated under the program, including engine downspeeding, automated manual transmissions, optimized intelligent torque management, optimized gear ratios for downsped engines, 6x2 axles, and aluminum wheels and driveshafts, to name a few. Taken as a whole, a number of SuperTruck technologies could achieve significant market penetration in the near term and could result in a cumulative savings of nearly 290 million barrels of oil by 2020.[6]

Lowered costs and increased performance of batteries to make plug-in electric vehicles more affordable with longer range. Between 1992 and 2012, DOE invested $1 billion dollars in battery R&D, which accelerated the deployment of technology and created $3.5 billion worth of economic value.[7] EERE's R&D efforts in this area helped bring hybrid-electric vehicles into the market during this period, which have now reached significant market penetration. Our R&D efforts also helped usher in the first and second generation of plug-in electric vehicles (PEVs) in the United States, and we have continued to further improve performance and reduce costs of these vehicles.

Starting in early 2002, the Vehicle Technologies Office (VTO) supported research at Argonne National Laboratory (ANL) to develop a new type of cathode for lithium-ion PEV batteries. Research over the course of eight years resulted in a new nickel-manganese-cobalt cathode in 2010. Members of this cathode material 'family' can operate at higher voltages and achieve much higher specific capacities than conventional cathode materials, resulting in batteries with higher energy density. After developing the cathode, ANL licensed the technology to BASF, LG Chem, General Motors, Envia, and TODA. Currently, LG Chem is producing batteries that use this technology in combination with other unique fuel-cell technology LG Chem developed with VTO's support. Both the original and next-generation Chevrolet Volt use batteries with this technology, as well as the Ford Focus EV. In fact, LG Chem has further improved on this chemistry for the next generation Volt, which has a 39% higher all-electric range while using substantially fewer battery cells.[8] In collaboration with Argonne, VTO is continuing to support research into batteries that will further increase PEV range, lower cost, and improve performance.

As of September 2015, EERE-supported research and development helped reduce the projected high-volume production cost of high-energy, high-power batteries to $264 per kilowatt-hour (kWh)—a more than 45% decrease from 2012 benchmarks, and a more than 70% decrease since 2008.[9] Automakers are taking advantage of these innovations to design electric vehicles

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[6] U.S. Department of Energy. DOE SuperTruck Program Benefits Analysis. Prepared by TA Engineering. December 2012. http://go.usa.gov/3SnC3.

[7] Inflation adjusted to 2014 dollars using U.S. Bureau of Economic Analysis GDP budget deflator. U.S. Department of Energy. *Benefit-Cost Evaluation of U.S. DOE Investment in Energy Storage Technologies for Hybrid and Electric Cars and Trucks*. Prepared by STI International. December 2013. http://go.usa.gov/3SnqJ.

[8] Comparison of Chevrolet 2015 Volt versus 2016 Volt; http://www.chevrolet.com/electric-hybrid-vehicles.html); 2016 Volt Range (http://www.chevrolet.com/volt-electric-car.html).

[9] DOE analysis of proprietary data provided in United States Advanced Battery Consortium (USABC) project reports.

(EVs) with lower prices and longer ranges that are entering the market today. For example, multiple automakers plan to deliver 200-mile range EVs for less than $40,000 around 2017.[10]

Dramatically reduced the cost and improved durability of fuel cell technologies. EERE R&D efforts have helped reduce fuel cell cost by 50% since 2006, now projected at $53/kW modeled cost based on lab technology projected for high volume manufacturing, and a four-fold increase in fuel cell durability.[11] R&D conducted at the national laboratories has been instrumental in achieving these advancements. The fuel cell program at Los Alamos National laboratory (LANL) serves as a prime example, with in-depth fuel cell knowledge developed over 40 years in the area. Today's fuel cell technology is based on the revolutionary breakthroughs in electrode fabrication developed at LANL, which resulted in an order of magnitude decrease in platinum loading in fuel cells. It is no surprise that LANL is leading the DOE's current public/private partnership effort in further enhancing fuel cell performance and durability to meet commercialization targets. As another example of national lab innovation, state-of-the-art catalysts developed at Argonne National Laboratory showed a threefold increase in mass activity in membrane electrode assembly (MEA) performance compared to conventional MEAs, demonstrating potential for further platinum loading reduction.

In 2015, we saw manufacturers introduce the first fuel cell electric vehicles (FCEVs) available for sale and commercial lease in select markets in the United States. DOE has independently validated more than 220 FCEVs from six automakers and more than 30 hydrogen stations over the last several years.

Developed prototype of Lightweight Concept Vehicle with significant weight reduction. Vehicle lightweighting is a key tool in developing the next generation of cars that achieve significantly greater fuel economy and reductions in greenhouse gas emissions. This is an effective method of saving fuel because a lighter vehicle requires less power to accelerate. This allows the engine—a large source of mass in the car—to be downsized while maintaining vehicle performance. For example, a 10% weight reduction can increase vehicle fuel economy by 6% to 8%, and for EVs lightweighting can increase how far the vehicle can travel on battery power.[12]

Lightweighting requires new materials to be developed to replace the conventional steel and other heavy car components without compromising strength, performance, or safety. Some of these new materials, such as high-strength steel and aluminum, are already in use, and advanced material innovations, such as composites made from polymer matrices, carbon fiber, and glass fiber, are working their way to market. New manufacturing processes have also been developed to process these materials at scale.

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[10] Davies, A. "Chevy Could Beat Tesla to Building the First Mainstream Electric Car," Wired. Accessed Aug. 21, 2015: http://www.wired.com/2015/01/chevrolet-bolt-ev.[11] DOE Hydrogen and Fuel Cells Program Record. *Fuel Cell System Cost – 2015*. Record #: 15015. October 22, 2015. http://www.hydrogen.energy.gov/pdfs/15015_fuel_cell_system_cost_2015.pdf.

[11] DOE Hydrogen and Fuel Cells Program Record. *Fuel Cell System Cost – 2015*. Record #: 15015. October 22, 2015. http://www.hydrogen.energy.gov/pdfs/15015_fuel_cell_system_cost_2015.pdf.

[12] U.S. Department of Energy, Quadrennial Technology Review. 2011. p.39. http://go.usa.gov/3SnC9.

Many of these materials and manufacturing innovations were validated through a recent lightweighting project supported by DOE, which culminated in the demonstration of a 23.5% lighter 2013 Ford Fusion.[13] This demonstration used today's materials with unique manufacturing processes that previously had not been implemented for automotive applications. As a result, DOE investment helped demonstrate that these lightweight materials could be used in innovative ways. Projected innovations in lightweighting and advanced high efficiency engines deployed in one quarter of the U.S. fleet could result in a savings of five billion gallons per year by 2030.[14]

Helped dramatically boost efficiency and lower emissions of gasoline and diesel engines being sold today. EERE co-funded research between 1997 and 2004 that aimed to design a diesel engine that was as quiet and clean as a gasoline engine, while providing a 30% improvement in vehicle fuel economy compared to gasoline-fueled equivalent. The fundamental design of the Cummins 5L V8 (8-cylinder) turbo diesel—produced in Cummins' plant in Columbus, IN—is based on technology developed under this EERE program. Following the EERE investments, Cummins collaborated with Nissan to optimize the use of the engine, which will be making its debut in Nissan's 2016 Titan full-sized pick-up truck.

What Comes Next: EERE's Sustainable Transportation R&D Priorities

While EERE has seen tremendous progress and outstanding achievements in our Sustainable Transportation portfolio, there is still significant work to be done in the transportation sector in order to meet our climate and energy security goals. EERE recently released its Strategic Plan for 2016-2020. In our plan we lay out a number of goals and technical targets, including goals and targets for our Sustainable Transportation portfolio, as well as our strategies to achieve them.

EERE has a number of high-priority RD&D efforts that will be advanced in fiscal year 2016 that will continue the Department's legacy of bringing new technologies and innovations to the U.S. transportation sector and to meet aggressive technology goals. I will highlight below several of these priorities across our portfolio.

***Plug-In Electric Vehicles*:** The EV Everywhere Grand Challenge, a bold DOE-wide initiative, seeks to enable the U.S. to produce a wide array of PEV models, including plug-in hybrids and all-electric vehicles that are as affordable and convenient as gasoline powered vehicles by 2022. Developed with key stakeholder input, the EV Everywhere Grand Challenge technology performance and cost targets guide DOE investments to reduce the combined battery and electric drive system costs of a PEV by up to 50% (by 2022, from a 2012 baseline). Hitting these targets would enable a range of plug-in electric vehicles to be directly cost competitive with conventional vehicles within five years.

***Heavy Duty Vehicles*:** Building off of the success of EERE's SuperTruck program, which will conclude in 2016, EERE will support new awards for a "SuperTruck II" initiative to research,

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[13] U.S. Department of Energy. Road to Fuel Savings: Ford, Magna Partnership Help Vehicles Shed the Pounds. August 2014. http://go.usa.gov/3SnCA.

[14] U.S. Department of Energy, Vehicle Technologies Office. Lightweight Materials for Cars and Trucks. Accessed October 2015. http://go.usa.gov/3SnrB.

develop, and demonstrate a greater than 100% freight efficiency improvement for heavy-duty Class 8 long-haul trucks by 2020 compared to a 2009 vehicle, with an emphasis on market readiness and performance, and to demonstrate applicability of these technologies to the growing number of heavy-duty Class 8 regional-haul vehicles as well. Improving the efficiency of regional haul trucks is becoming more important as fleets shift from sleeper cab to day cab tractors that can be optimized for shorter hauls. Projects will include RD&D of technologies that improve engine efficiency and emission control, advanced transmissions and hybridization, waste energy recovery, aerodynamic drag of the tractor and trailer, tire rolling resistance, lightweight materials, and auxiliary power units to reduce engine idling, along with other technologies as needed to meet the goal.

Co-Optimization of New Fuels and Vehicle Systems: Building on prior-year and ongoing fuel properties and advanced combustion activities, EERE is establishing links across fuels and engines early in the R&D cycle that will enable a new, synergistic and complete systems-based approach to creating optimized powertrains. Co-development of engines and fuels as an integrated system will allow future engines to operate at peak efficiency for a higher portion of drive cycles. The ultimate goal of the effort is cost-effective, lower-carbon fuels for high performance efficient engines. These systems seek to deliver up to 60% lower greenhouse gas emissions than conventional engines using conventional fuel on a lifecycle basis while reducing per-vehicle petroleum consumption by 30 percent--cutting oil use by up to 4.5 Billion gallons between 2030 and 2040.[15] Through a combination of competitively-awarded projects and work with National Laboratories, activities will be structured to apply to a wide range of current and potential future lower-carbon fuels. Led by a consortium of National Laboratory experts and in consultation with key industry stakeholders, work in 2016 will involve studying the co-optimization of fuel properties/formulation and engine efficiency, as well as techno-economic criteria.

Advanced Materials R&D: In support of the Administration's Materials Genome Initiative and as part of DOE's Clean Energy Manufacturing Initiative, EERE has established another, crosscutting effort to develop advanced materials that can reduce the cost and improve the performance of components, and to accelerate the deployment of lightweight materials and manufacturing processes for automotive use. Work in this area includes efforts to develop alternatives to platinum group metal (PGM) catalysts, electrodes, and interfaces, which have the potential to significantly reduce the cost of fuel cells. It will also focus the use of high-performance computing and high-throughput materials experimentation, to capture the effects of processing and end use and dramatically accelerate the development of high strength, high formability, corrosion resistant, and low cost magnesium sheet alloys for vehicle lightweighting.

Grid Modernization: U.S. prosperity and energy innovation in a global clean energy economy depend on the modernization of the electric grid—a modern grid that enables high penetration of variable renewable electricity generation, supports wide-spread adoption of PEVs, and utilizes energy storage technologies including fuel cells, to provide secure, reliable and clean electricity to consumers across the country.

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[15] EERE Program Fact Sheet. *Co-Optimization of Fuels and Engines: Accelerating the Path to Economic and Sustainable Fuels and Vehicles.* SAND2015-2142 M. April 2015.

To support this transformation and align with DOE's Grid Modernization efforts, EERE's Sustainable Transportation programs focus on PEV-to-grid integration and the technologies needed to fully integrate PEVs into the distribution system in a safe, reliable, and cost-effective manner. This includes VTO work to develop and demonstrate new devices (e.g. low-cost communications-capable energy meters), systems, and algorithms to enable advanced control of PEVs across the electricity distribution system, as well as specific research to integrate plug-in vehicle charging management with building energy management systems. Additionally, VTO will continue to provide technical support to promote the development of standards that ensure a safe and reliable physical, electrical, and communications interface between vehicles and the electric grid. The Fuel Cell Technologies Office will also focus on developing controls and associated system architectures needed to manage a diverse set of resources and grid assets, including fuel cell technologies, electrolyzers, and energy storage across the distribution system; investigating how reversible fuel cells can help mitigate variable generation and enable energy from the system to be more easily dispatched over the course of a given day; developing low cost sensors to provide visibility to grid operators on what services reversible fuel cells and electrolyzers can provide to the grid; and determining how reversible fuel cells and electrolyzers can provide flexibility to the grid.

Research on Connected and Automated Vehicles: Connected and automated vehicles (CAVs) are expected to have important impacts on transportation energy use, though key questions remain on whether those impacts will be positive or negative. To evaluate these impacts, EERE has partnered with the University of Michigan, and both Argonne and Idaho National Laboratories to examine how drivers interact with different technologies in connected vehicles, including whether or not those technologies help them drive more efficienctly. During the project, researchers will work with privately-owned vehicles in the Ann Arbor area to collect information about how they are driven and how much energy they use. Better understanding the benefits and challenges of connected vehicles can help vehicle designers improve vehicle efficiency, reducing carbon pollution, improving energy security, and saving American drivers money. This activity, as well as other systems-level analyses, will provide information to the Vehicle Technologies Office to help determine the impact of the emerging CAV technologies on vehicle research and development efforts, and to guide future potential investments in this space.

Conclusion

Our country is faced with a national imperative to seize the enormous economic opportunity of leading the global transition to a clean energy economy. Building on our past success and investing in innovative research and technology in the clean energy sector is expected to not only cut oil use and reduce carbon emissions and pollution, but to also create jobs and catalyze economic growth.

As President Obama and other world leaders affirmed in the launch of the Mission Innovation initiative, solving our energy and climate challenges, and achieving the related benefits, will require the rapid acceleration of new technology development and its diffusion into the market.

EERE's sustainable transportation portfolio in particular holds the potential to be transformative for the Nation. Two recent studies[16] [17] concluded that a portfolio of EERE-supported technologies—including fuel cell electric vehicles, plug-in electric vehicles , advanced combustion technologies, vehicle light-weighting and largescale use of biofuels—could reduce domestic consumption of petroleum in light-duty vehicles by 40% by 2030 and 80% by 2050. The analyses also found that these changes could be achieved through multiple pathways using various combinations of technologies in the EERE portfolio.

Many of these technologies are just beginning to be introduced in significant volumes into the commercial marketplace, but market barriers remain in limiting the speed of deployment. EERE's Sustainable Transportation portfolio plays a critical role as we continue to work with our national Laboratories and private-sector partners to move more of this cutting-edge technology to commercialization.

While we have made enormous gains, we must maintain our focus on building a robust innovation ecosystem in order to capture the full set of opportunities now and in the decades to come. The transformation of global energy markets to effectively address climate change requires extraordinary ways and means, and clean energy innovation has a preeminent role in this transformation. Meeting our global climate challenges while providing affordable, reliable and secure energy supplies will require radical acceleration of technology development and diffusion.

DOE will continue to play a large role in shaping the future of sustainable transportation and will drive further innovation within the U.S. automotive industry. We look forward to continuing to work with Congress and this Committee to support sustainable transportation and boost U.S. competitiveness and job creation.

Thank you again for the opportunity to speak to this important issue, and I will be happy to answer any questions.

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[16] Transitions to Alternative Vehicles and Fuels, National Research Council, 2013.
[17] Transportation Energy Futures, EERE, 2013.

The CHAIRMAN. Thank you, Mr. Friedman.
Mr. Bainwol, welcome.

STATEMENT OF MITCH BAINWOL, PRESIDENT AND CEO, THE ALLIANCE OF AUTOMOBILE MANUFACTURERS

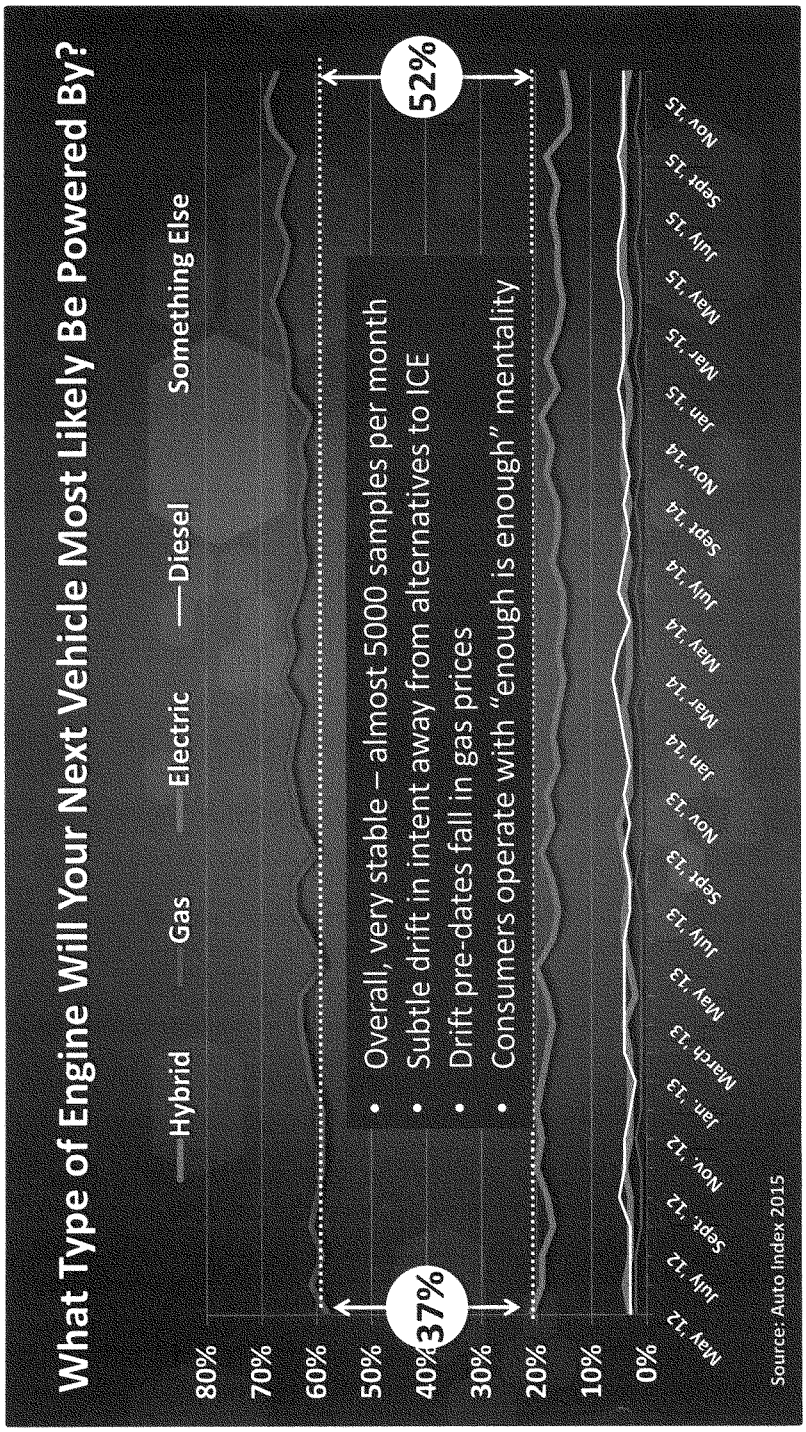
Mr. BAINWOL. Thank you, Chairman Murkowski and members of the Committee. I appreciate the chance to be here today on behalf of 12 OEMs, the D3 and nine others from Europe and from Japan.

Our guys and other OEMs are investing massively in R and D, $109 billion last year, and that is 16 percent of the global R and D spent. That's roughly four times our economic waste, so we're prospering right now with sales and we're investing back into R and D and that's paying real dividends.

As I got up this morning I looked at the weather and realized I had to travel in 20 miles and tried to figure out the best way to go. I turned on my NAV, and I took a path that was different than any other I'd ever taken over the last 20 years of commuting from Fairfax. NAV directed me to Washington in a fashion that was quicker, so I saved time, was more productive, was cleaner and was more fuel efficient. That struck me as kind of a metaphor for today. Technology is bringing about a convergence of these social objectives. We want mobility to be cleaner, we want it to be safer, we want it to be more efficient, and that's exactly what we're doing here today.

I thought I'd go through some slides rather than read a statement, and if I can I'd do it fairly quickly and ask that you be patient as I try to get through them.

[The information referred to follows:]


What Type of Engine Will Your Next Vehicle Most Likely Be Powered By?
Hybrid
Gas
Electric
Diesel
Something Else
80%
70%
60%
50%
40%
30%
20%
10%
0%
37%
52%
• Overall, very stable – almost 5000 samples per month
• Subtle drift in intent away from alternatives to ICE
• Drift pre-dates fall in gas prices
• Consumers operate with "enough is enough" mentality
May '12
July '12
Sept '12
Nov '12
Jan '13
March '13
May '13
July '13
Sept '13
Nov '13
Jan '14
Mar '14
May '14
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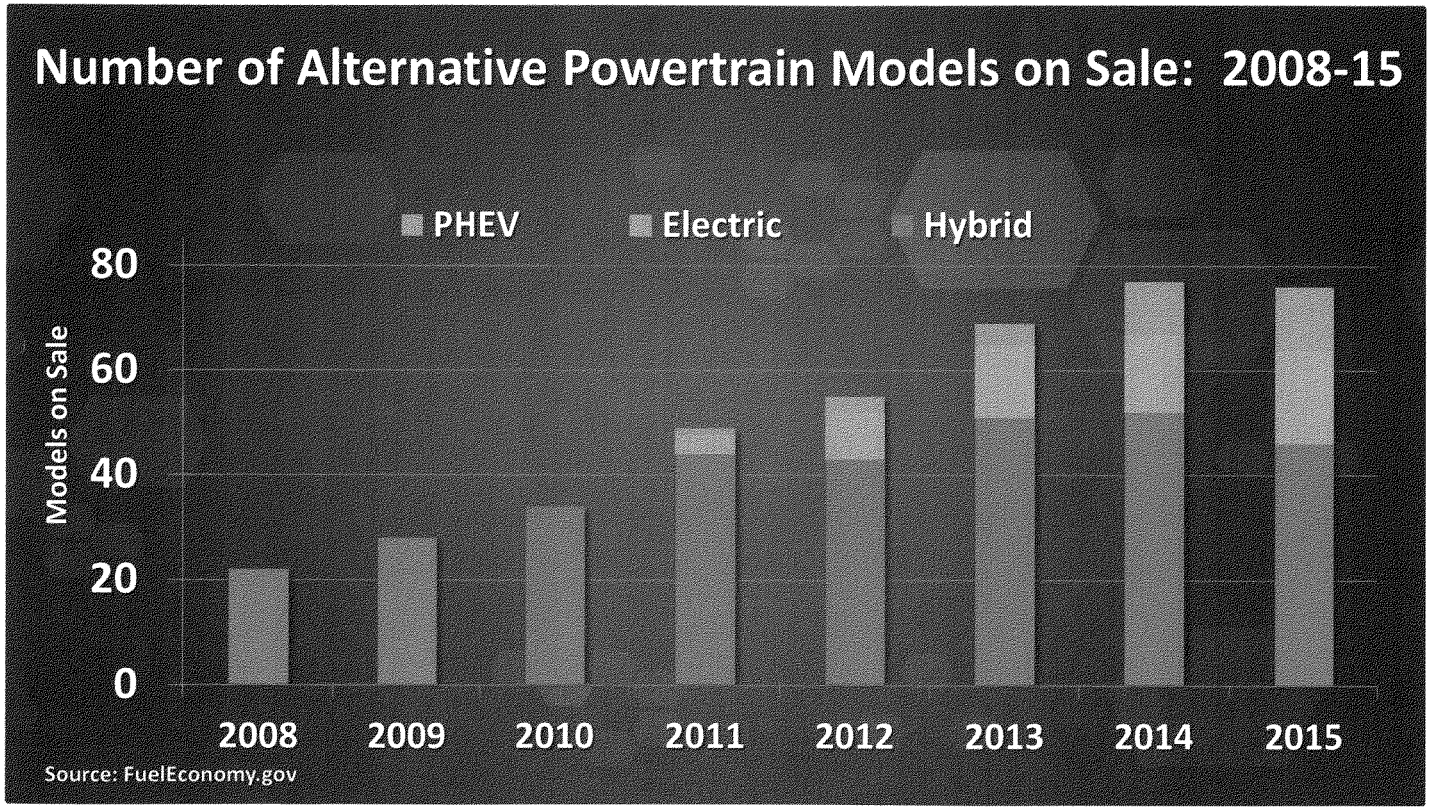
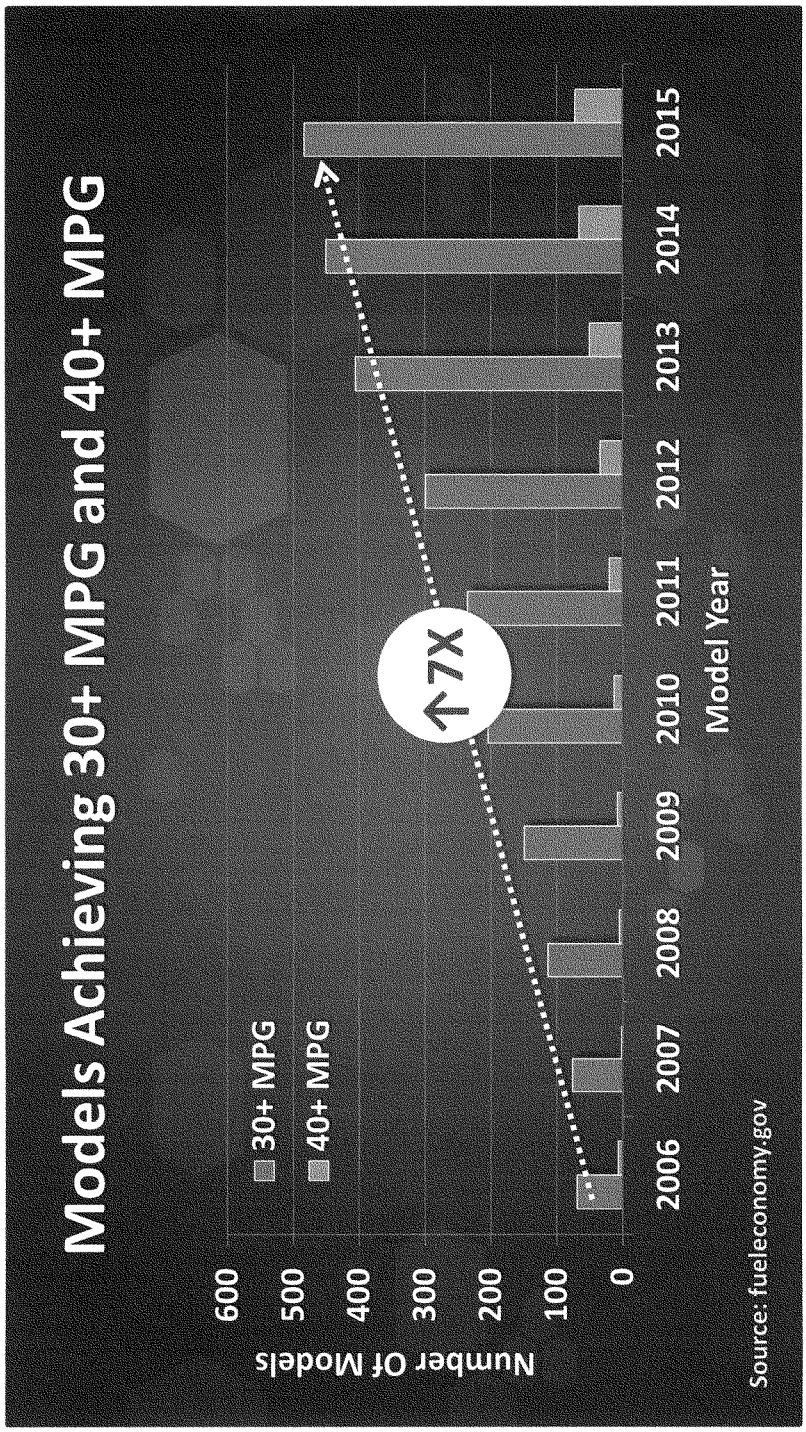
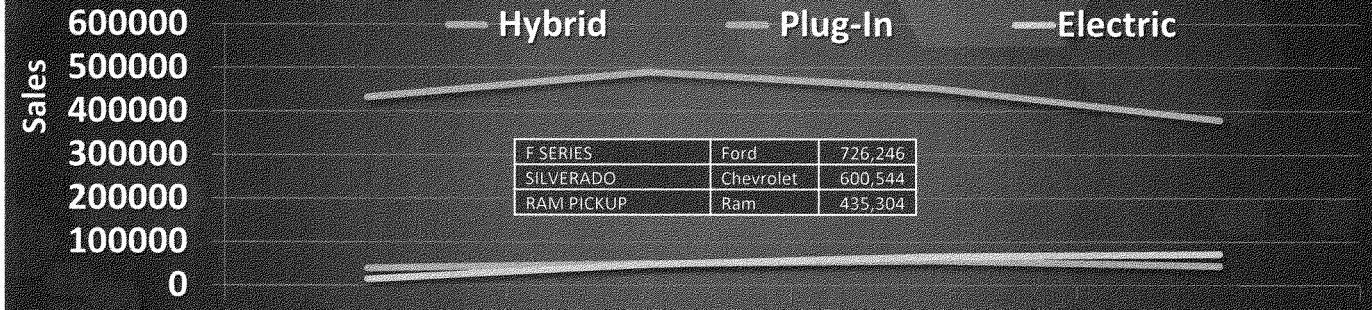
Nov '14
Jan '15
Mar '15
May '15
July '15
Sept '15
Nov '15
Source: Auto Index 2015


Number of Alternative Powertrain Models on Sale: 2008-15
PHEV
Electric
Hybrid
Models on Sale
80
60
40
20
0
2008
2009
2010
2011
2012
2013
2014
2015
Source: FuelEconomy.gov

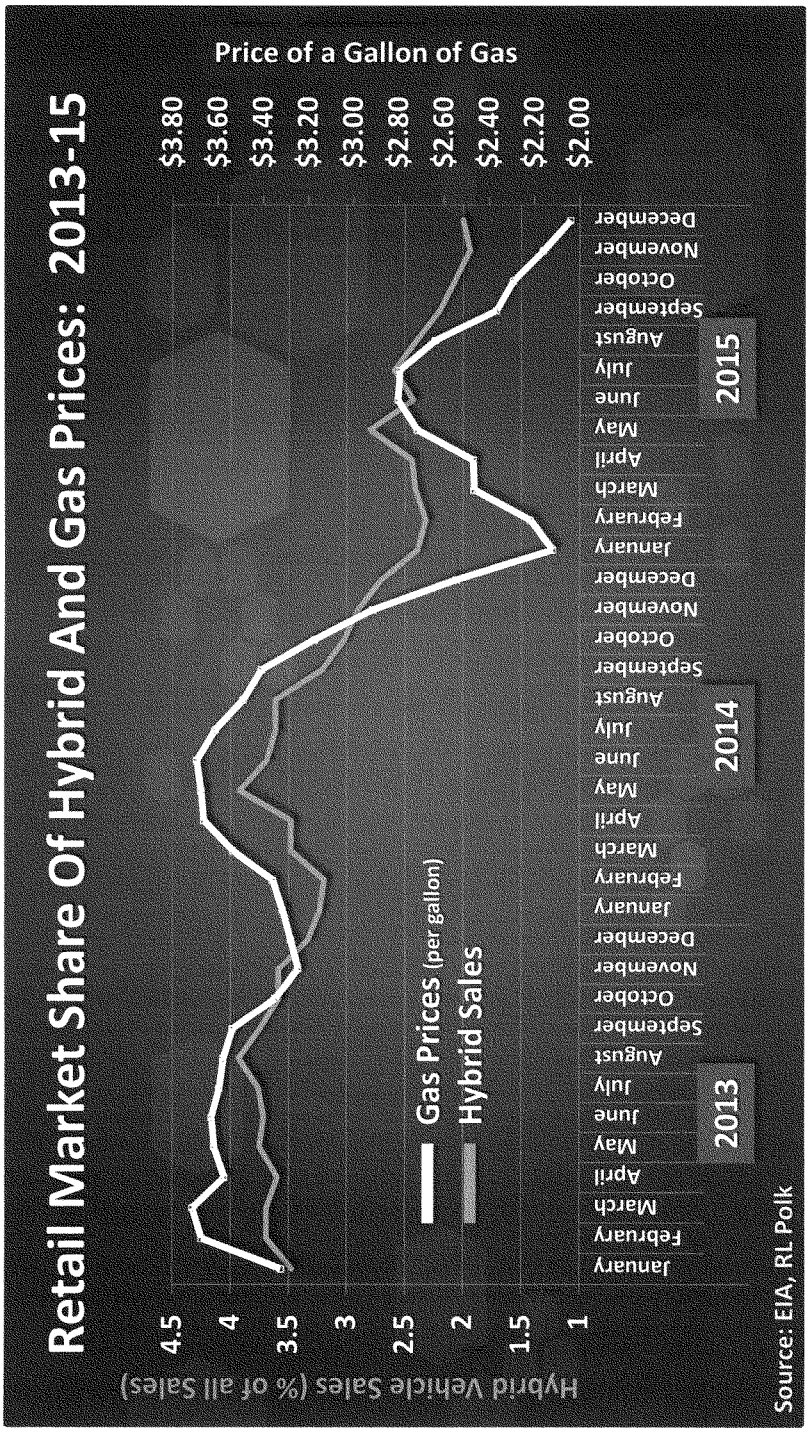

Models Achieving 30+ MPG and 40+ MPG
30+ MPG
40+ MPG
↑7X
Number Of Models
600
500
400
300
200
100
0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Model Year
Source: fueleconomy.gov

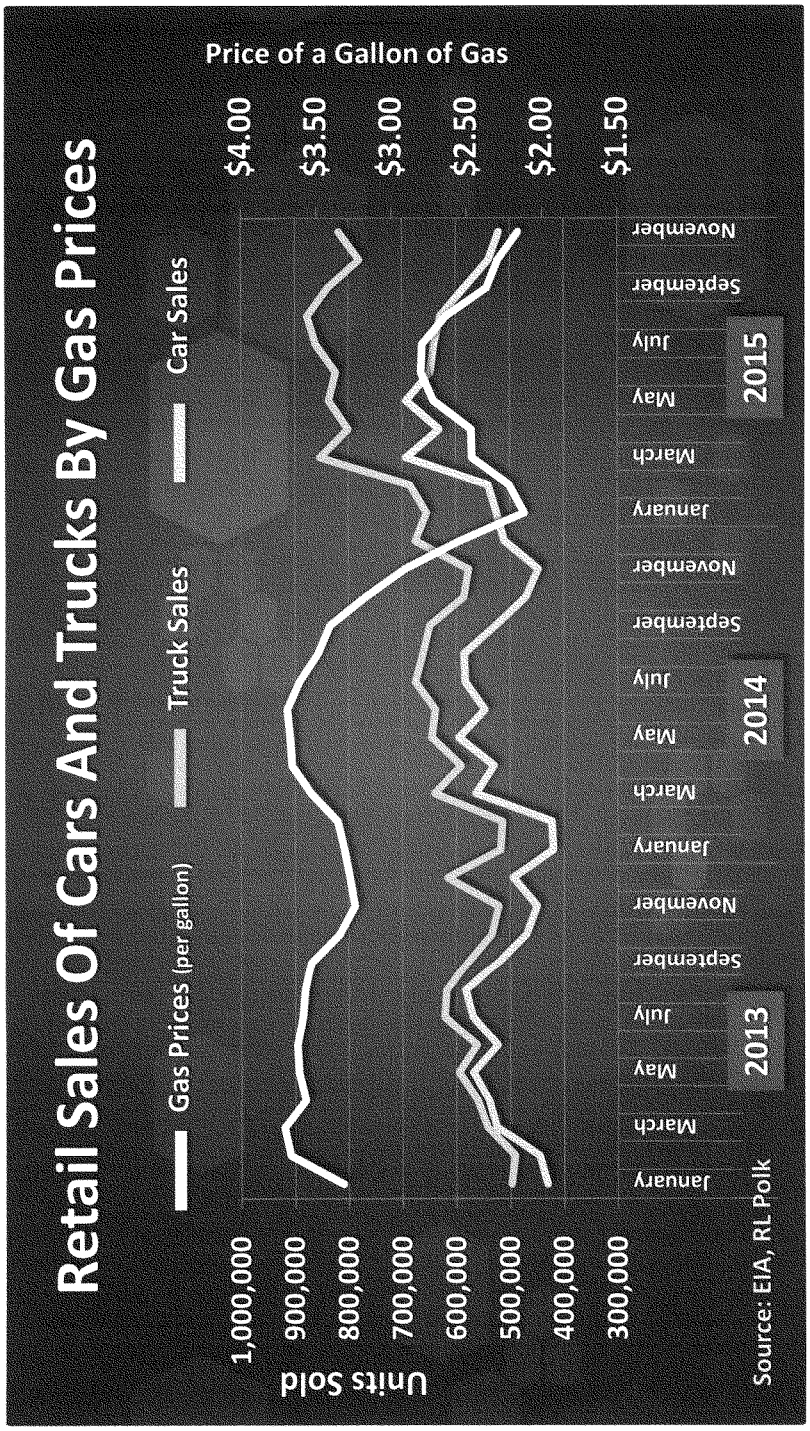
Recent Sales of Alternative Powertrains

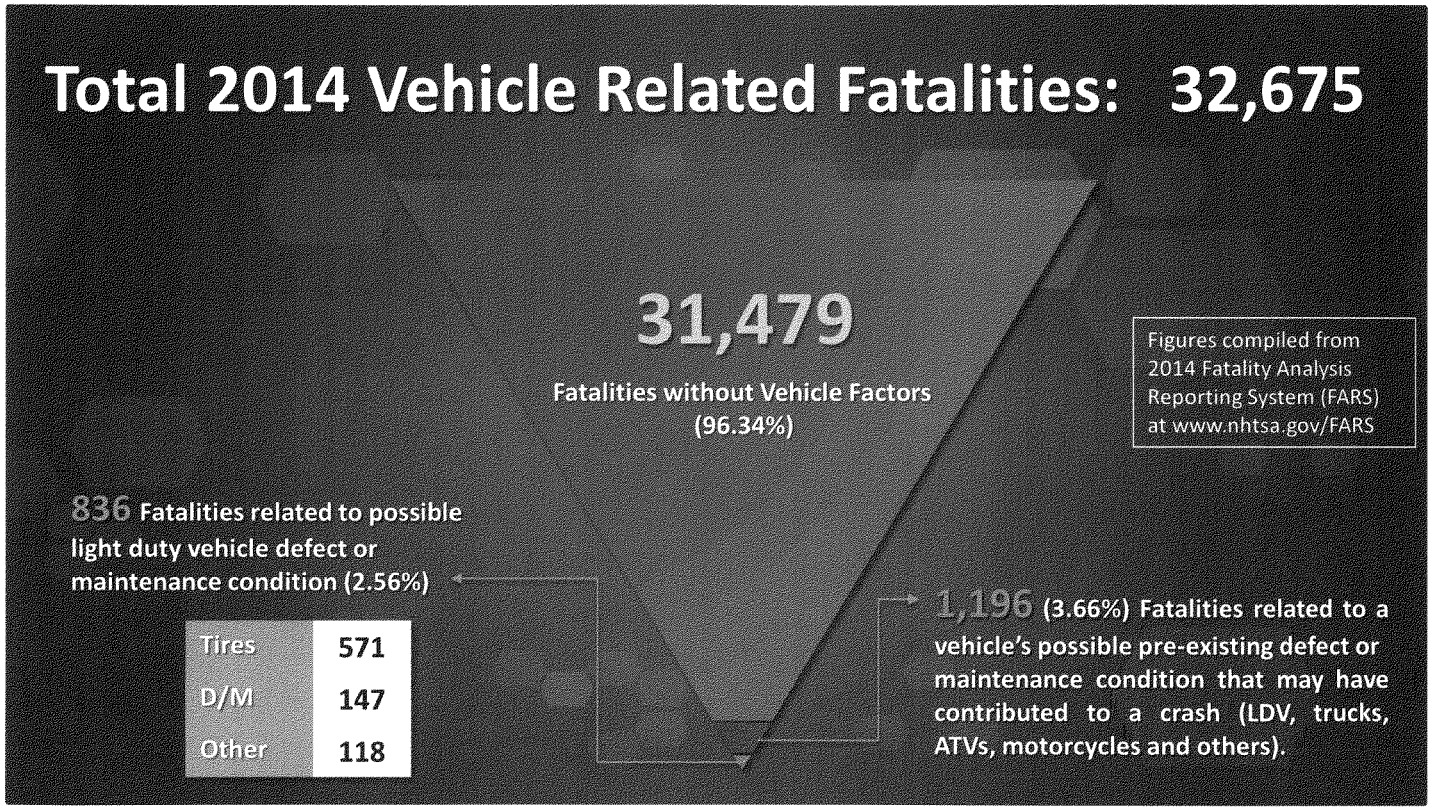


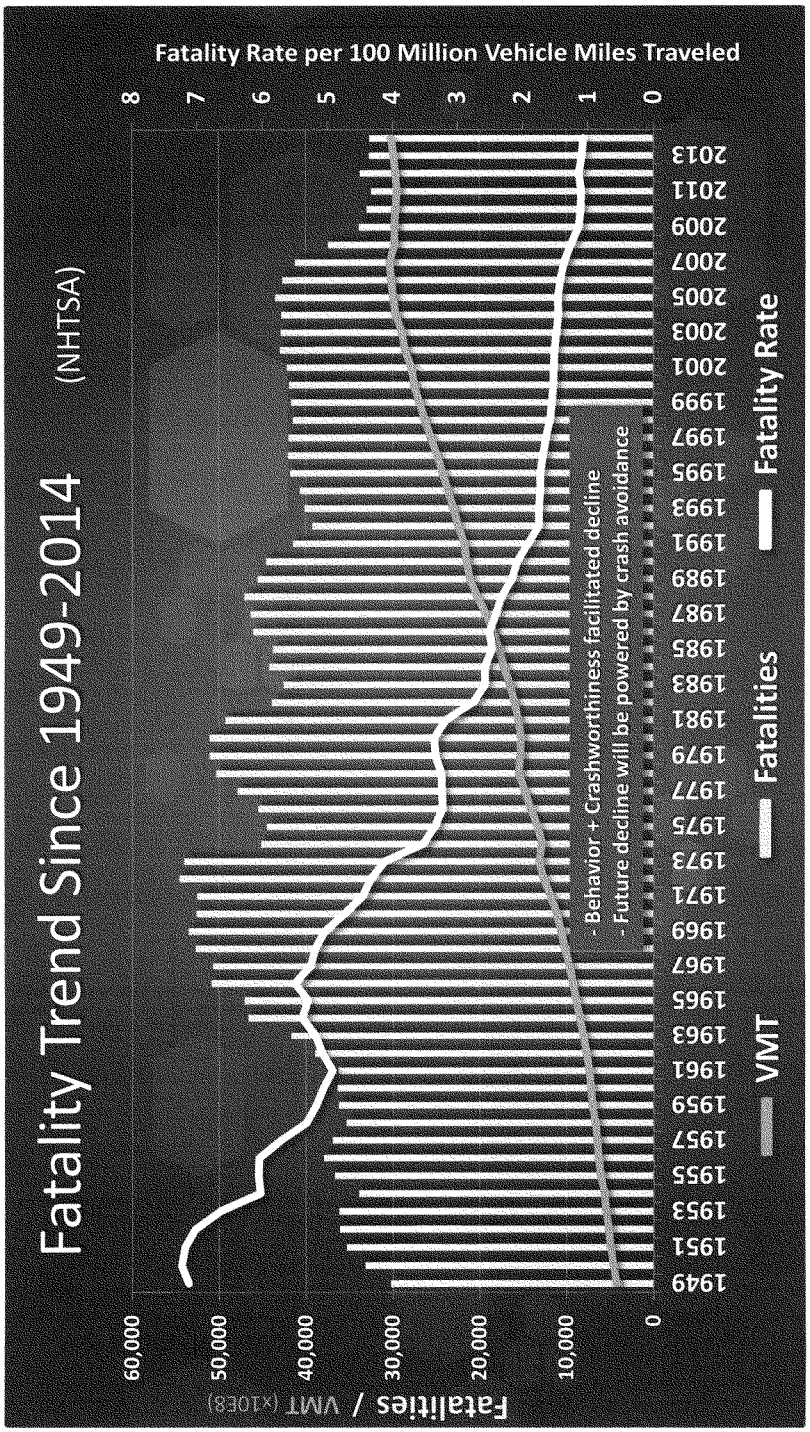
F SERIES	Ford	726,246
SILVERADO	Chevrolet	600,544
RAM PICKUP	Ram	435,304

	2012	2013	2014	2015
Hybrid	431,798	489,413	451,831	378,402
Plugin	38,585	48,957	55,441	43,458
Electric	13,941	47,595	65,347	70,823

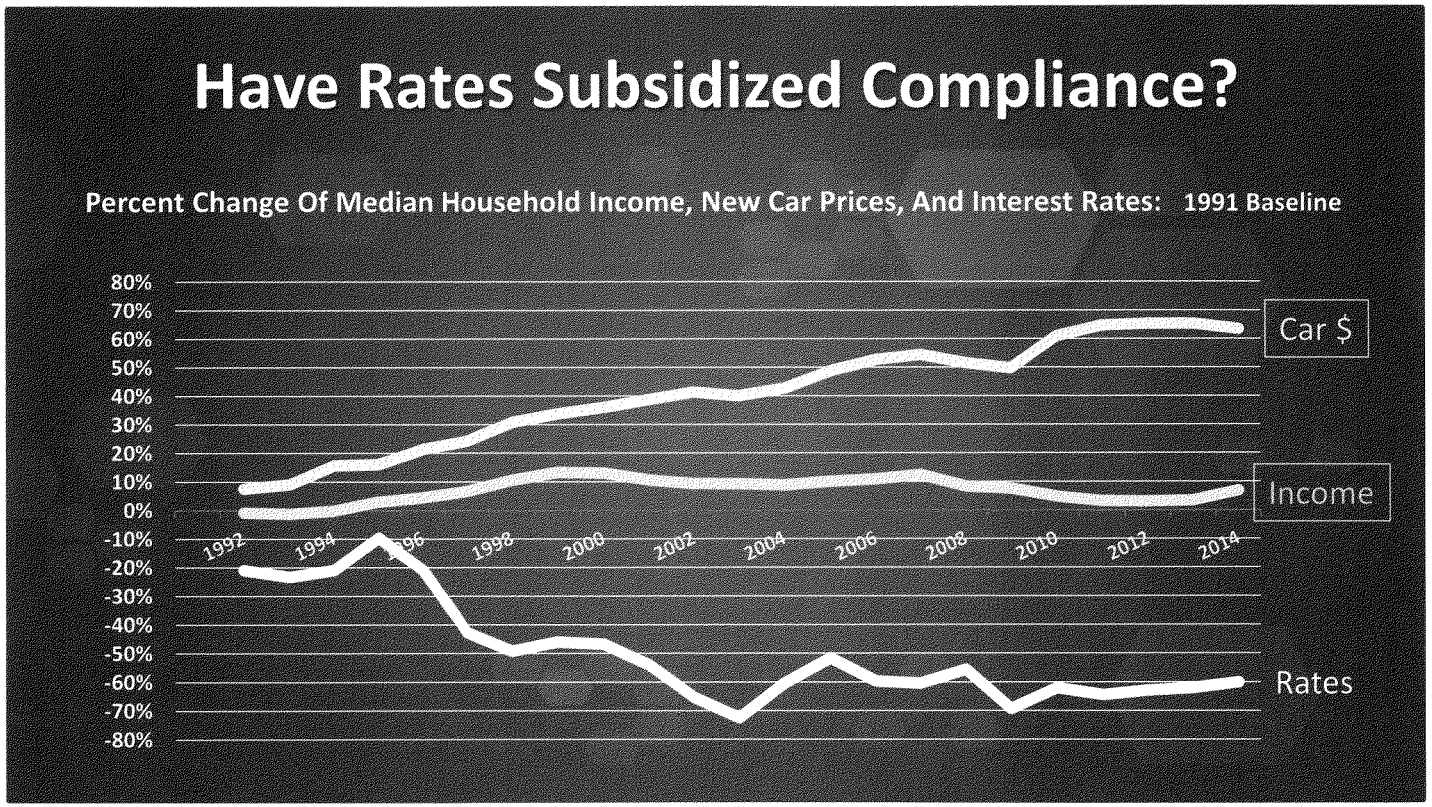

Retail Market Share Of Hybrid And Gas Prices: 2013-15
Price of a Gallon of Gas
$3.80
$3.60
$3.40
$3.20
$3.00
$2.80
$2.60
$2.40
$2.20
$2.00
Hybrid Vehicle Sales (% of all Sales)
4.5
4
3.5
3
2.5
2
1.5
1
Gas Prices (per gallon)
Hybrid Sales
2013
January
February
March
April
May
June
July
August
September
October
November
December
2014
January
February
March
April
May
June
July
August
September
October
November
December
2015
January
February
March
April
May
June
July
August
September
October
November
December
Source: EIA, RL Polk


Retail Sales Of Cars And Trucks By Gas Prices
Gas Prices (per gallon)
Truck Sales
Car Sales
Price of a Gallon of Gas
$4.00
$3.50
$3.00
$2.50
$2.00
$1.50
Units Sold
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
January
March
May
July
September
November
2013
January
March
May
July
September
November
2014
January
March
May
July
September
November
2015
Source: EIA, RL Polk


Total 2014 Vehicle Related Fatalities: 32,675
31,479
Fatalities without Vehicle Factors (96.34%)
Figures compiled from 2014 Fatality Analysis Reporting System (FARS) at www.nhtsa.gov/FARS
836 Fatalities related to possible light duty vehicle defect or maintenance condition (2.56%)
Tires 571
D/M 147
Other 118
1,196 (3.66%) Fatalities related to a vehicle's possible pre-existing defect or maintenance condition that may have contributed to a crash (LDV, trucks, ATVs, motorcycles and others).


Fatality Trend Since 1949-2014
(NHTSA)
Fatality Rate per 100 Million Vehicle Miles Traveled
Fatalities / VMT (x10E8)
- Behavior + Crashworthiness facilitated decline
- Future decline will be powered by crash avoidance
VMT
Fatalities
Fatality Rate

Have Rates Subsidized Compliance?



The first one will take a bit of time. It is titled,"What Type of Engine Will Your Next Vehicle Be?" We do extensive polling. We do about 5,000 samples of consumers a month, literally every day 167 folks, and we ask them what kind of power train their next vehicle will be. So this is aspirational.

The good news here is, as you can see in May of '12 when we started this, roughly 20 percent say they wanted to go to a hybrid. A hybrid becomes a proxy for alternative power trains for most folks. Roughly 60 percent said they wanted a gas engine.

If you look at the line over the last three and a half years, you see the hybrid number falling, drifting down and you see the gas number rising. That's a little counterintuitive in a world in which we're offering more models, more hybrid and electric models, in showrooms.

What's going on is we've made progress with the ICE, with the internal combustion engine, that is so profound that when a consumer goes into a showroom they discover that there are new cars getting roughly 25 percent more fuel efficiency than their old car. The success of the conventional engine is it's making it harder to justify the delta to the electric, and that's a challenge for us where going electric is a worthy goal but there is a market challenge there.

The next slide just speaks to the number of alternative power train models there are for sale. You can see that in 2008 there were roughly 21, 22 models. That is now up close to 80, and that's a combination of electric hybrid and plug ins.

The next slide shows the number of models achieving 30 plus MPG and 40 plus MPG, and what you see there is really profound success. This is part of the value of the investment. It's a seven times increase in number of models. So the models are in the showrooms. The opportunity to buy the more fuel efficient vehicles are there. And on the conventional side, that is making the choice to go to alternative power trains a little bit more complicated.

Then you look at the sale of alternative power trains and you can see that there's been a dip by 2015. It slowed down. Part of that is gas prices and part of that is the success of the conventional engine.

The next slide shows retail market share of hybrid and gas prices, and it looks like synchronized swimming. What you have is a direct linear relationship between gas prices and the sale of hybrids.

A similar pattern with the sale of cars and trucks is the next slide. And I'm moving quickly because I'm running out of time. I want to spend a second on safety.

The slide titled,"Total 2014 Vehicle Related Fatalities" shows that we lost 33,000 Americans on the road in 2014 which is obviously an awful number that we're all working to drive down. But I think it's worthwhile to point out that 97 percent of those had nothing to do with the vehicle. It was human error, and that's why technology is so important. Technology can mitigate human error.

The next slide puts the fatality number into context. That's a 65-year trend line. The vertical bars are the absolute number of folks we've lost. And you can see in 2013–2014 it's roughly where we were in 1949 but the vehicle miles traveled is dramatically higher

and the number of drivers is dramatically higher. So the yellow line shows the progress we've achieved which is a function both of less drunk driving, more folks using belts and improved crash worthiness technology.

The next chapter of progress on fatalities will come from the technology we're talking about here today, I would make that point that I started with in terms of the NAV. All these technologies are not about safety, they're not about green. It's about maximizing all these social objectives.

There's a convergence. When you avoid a crash it is both very green because there have been injection implications and there's also very safe and it's very productive. So crash win technologies, whether it's the advanced driver assist or whether it's a fully autonomous vehicle, have a profound, almost magical implication for the economy and for life. And so we appreciate the focus on innovation today, and we just focus on the convergence of these benefits.

I'd make one last point, if I could, and that is this last slide shows the fundamental dilemma that we've got. This shows a 25-year pattern. The blue line is year over year change in household income, fundamentally flat. The salmon, I guess that's a salmon-colored line, that rises is the price of the auto which in part is being driven up by compliance responsibilities. And the yellow line is interest rates, year over year change in interest rates.

So in effect what we've done is we have financed the ability to comply with more expensive vehicles based on compliance by lower interest rates and with longer terms. And as interest rates begin to rise we've got to be mindful of this equation because it produces a challenge that may have jobs implications in terms of the manufacture of vehicles but also adoption implications in terms of turning over the fleet to vehicles that are much more efficient.

And with that, I'd say, thank you.

[The prepared statement of Mr. Bainwol follows:]

AUTO ALLIANCE
DRIVING INNOVATION

STATEMENT

OF

THE ALLIANCE OF AUTOMOBILE MANUFACTURERS

BEFORE THE:

SENATE ENERGY AND NATURAL RESOURCES COMMITTEE

JANUARY 21, 2016

PRESENTED BY:

Mitch Bainwol
President and CEO

Chairman Murkowski and Ranking Member Cantwell, on behalf of the members of the Alliance of Automobile Manufacturers (Alliance), I appreciate the opportunity to testify today before the Committee on the innovative technologies that automakers are currently integrating into their vehicles – making today's automobile among the most sophisticated technology owned by consumers.

Alliance members account for 75 percent of annual car and light-truck sales by revenue in the United States. The Alliance includes amongst its diverse membership companies headquartered in the U.S., Europe and Asia, including the BMW Group, Fiat Chrysler Automobiles US, Ford Motor Company, General Motors Company, Jaguar Land Rover, Mazda, Mercedes-Benz USA, Mitsubishi Motors, Porsche, Toyota, Volkswagen Group of America and Volvo Car Group.

This hearing could not have come at a better time – fresh off a record-breaking year for auto sales. Automakers sold 17.5 million cars and light-trucks in 2015, a 5.7% sales increase over 2014. Considering where we were just seven years ago – in the midst of the worst economic crisis since the Great Depression – this is especially heartening. These new vehicles are among the safest, environmentally cleanest and most fuel efficient we've ever seen on U.S. roads.

We are experiencing the most innovative time in automotive history. Automakers continue to drive a revolution in vehicle safety and fuel-efficient technologies. Until recently, these goals – maximizing safety and maximizing environmental progress - were not always aligned. But the very nature of today's crash avoidance technology helps harmonize safety and environmental objectives. Crash avoidance and connectivity technologies will help prevent crashes from happening in the first place, which will lead to lower congestion and result in lower overall carbon and emission levels.

Virtually every aspect of today's automobile is high-tech. As a result, automakers are consistently recognized as leaders in research and development (R&D) investments, in the U.S. and globally. A 2013 report by The Boston Consulting Group found that almost half of the world's top 20 "Most Innovative Companies" were automakers. In fact, last year's top 20 list included more automobile companies than technology companies. To keep pace with ever-growing consumer demands for sophisticated new technologies, recent studies show that automakers spend more than $100 billion annually on R&D — including $18 billion in the U.S. alone. It's an astounding commitment to innovation that is paying off for families and society.

A number of factors are driving this wave of automaker innovation. Companies are working to increase vehicle fuel-efficiency, while developing even more capable hybrid and electric models, more efficient power trains and lighter car bodies. At the same time, automakers are building safer vehicles with cutting-edge technologies like automatic emergency braking systems and vehicle-to-vehicle communications. A recent report by the U.S. Department of Transportation described innovations by automakers as a "revolution in safety."

Automakers also recognize that a top priority for our nation is to put more fuel-efficient vehicles on our roads to help drive us ever closer to energy independence. As a result, the industry is rapidly deploying a range of fuel-efficient technologies, providing consumers a wide set of options that meet their lifestyle needs. In 2015, there were more than 490 models available to consumers that achieved an average of 30 miles per gallon (mpg) – up 600 percent from 2006 when there were only 69 models. And, the number of models reaching 40 MPG is growing as well, with 76 models available to consumers in 2015 – nearly a 1,000 percent increase from 2006 when there were only 7 models.

Earlier this month, at the Consumer Electronics show in Las Vegas, GM CEO, Mary Barra, summed it up nicely, stating "I have no doubt the auto industry will change more in the next five to 10 years than it has in the last 50." And that change – this evolution – has begun. While it will still be a few years before consumers will find fully autonomous vehicles on showroom floors, the American consumer already can enjoy vehicles equipped with crash avoidance or "driver assist" technologies that are focused on helping drivers avoid crashes or reducing their severity of injuries that vehicle occupants or pedestrians would have been exposed to just a few years ago.

Keep in mind, driver error remains the primary cause of 94 percent of crashes, according to the National Highway Traffic Safety Administration (NHTSA). That's why technologies that address human error have the potential to improve safety outcomes. Crash avoidance technologies employ sophisticated software to interpret data from sensors, cameras, or radar-based technologies that allow vehicles to sense the environment around them and alert drivers of impending dangers. Some of these technologies – like blind spot warning for example - alert the driver about risks ahead or behind and potentially help him or her avoid a crash by focusing the driver's attention on the driving task. Other technologies intervene and impact the operation of the vehicle to prevent or mitigate the severity of the crash. Intervention technologies can be invisible to the driver – electronic stability control is an example – while others actively impact operation of the car. Examples include automatic emergency braking, lane keeping assist, adaptive cruise control and automatic high beam lighting.

Even more exciting is the next phase of vehicle safety technology – cars that "talk" to each other and "talk" to the surrounding environment, often referred to as vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communications. These technical communications systems that rely on wireless spectrum allocated for public safety are designed to allow vehicles to communicate with one another and the environment around them to enhance safety and eliminate congestion in our cities and on our highways. NHTSA estimates connected vehicle technology could potentially mitigate or eliminate up to 80 percent of crash scenarios involving non–impaired drivers. The implications are profound, and justify why both automakers and the government have invested hundreds of millions of dollars in the development of connected vehicle technologies.

The potential for these innovative vehicle technologies to help reduce the number and severity of crashes is promising. But there are other benefits as well. When a crash is avoided, the traffic congestion resulting from the crash is eliminated. Reduction in traffic

congestion means less fuel is wasted by vehicles idling in traffic, thereby cutting down on greenhouse gas emissions. Crashes that don't happen also help bring down insurance costs, and productivity rises as drivers waste less time in traffic or time spent recovering from injuries sustained in automobile crashes. That's good for families, commuters and businesses that rely on a safe and efficient roadway system across the country.

We refer to these technologies collectively as "convergence" technologies because they advance safety, mobility, and environmental goals. NHTSA's automated vehicle white paper spells out the convergence of the environment and safety by noting:

> "Vehicle control systems that automatically accelerate and brake with the flow of traffic can conserve fuel more efficiently than the average driver. By eliminating a large number of vehicle crashes, highly effective crash avoidance technologies can reduce fuel consumption by also eliminating the traffic congestion that crashes cause every day on our roads. Reductions in fuel consumption, of course, yield corresponding reductions in greenhouse gas emissions. To the extent vehicles can communicate with each other and with the highway infrastructure, the potential for safer and more efficient driving will be increased even more."

And just last week, while announcing new initiatives to accelerate vehicle safety innovations, including new guidance on autonomous vehicles, DOT Secretary Foxx stated the following:

> "We are on the cusp of a new era in automotive technology with enormous potential to save lives, reduce greenhouse gas emissions, and transform mobility for the American people. Today's actions and those we will pursue in the coming months will provide the foundation and the path forward for manufacturers, state officials, and consumers to use new technologies and achieve their full safety potential."

Despite the numerous benefits of these vehicle technologies, automakers still face several roadblocks to their wide scale deployment.

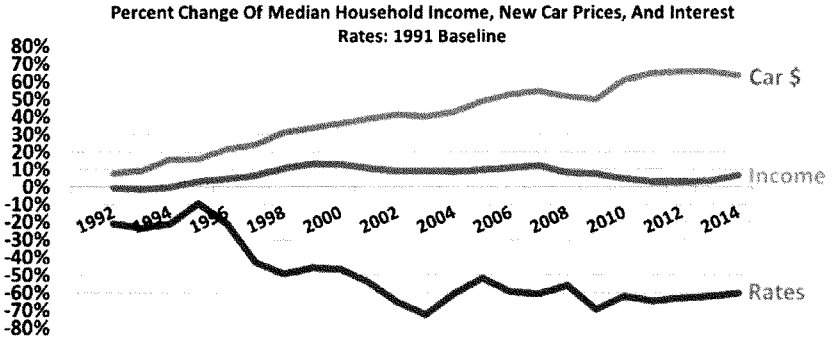
We are sometimes caught in the middle between the goals of public policy and the preferences of consumers. National fuel economy requirements – which call for a fleet average of 54.5 MPG by 2025 – are a mandate not on production but on customer purchases. So too is the Zero Emission Vehicle (ZEV) program – which requires that plug-in hybrids (PHEVs), battery electric and fuel cell vehicles (BEVs and FCVs, respectively) comprise 15.4% of all car sales in California and the northeast by 2025. It doesn't matter what automakers produce, just what consumers buy.

And while EPA and the California Air Resources Board (CARB) are understandably focused primarily on reductions of greenhouse gas emissions, consumers have a broad array of goals in mind when they buy a vehicle – everything from functionality, cost of operation, design, technology, safety features, performance, hauling, towing and reliability. Do consumers like fuel efficient vehicles? Absolutely. But are they always

looking to optimize fuel efficiency solely? No. And that's especially true when gas prices have collapsed and the fuel efficiency of conventional engines has improved so significantly.

We see this reflected in vehicle sales figures. Earlier in my testimony, I mentioned that automobile manufacturers sold more cars than ever last year; however, of the 17.5 million vehicles sold, only 116,548 (or less than one percent) were PHEVs or BEVs. In fact, automakers have sold 400,639 PHEVs and BEVs since 2010 – far short of President Obama's goal to have 1 million on U.S. roads by 2015.

The following chart illustrates how interest rates, household income and car prices have evolved over the last 24 years.



As you'll note, car prices have risen (in part to accommodate the costs of compliance with safety, energy and environmental requirements), household income has essentially been flat, and interest rates, until recently, have shown decline. In effect, in the context of stagnant income, increased vehicle costs have essentially been paid for by lower interest costs and increases in the duration of loans. As interest rates rise, higher financing costs, along with increasing compliance obligations, could make it more difficult for some families to replace their old car with a new one. And that of course is a problem on lots of levels. First, it reduces demand for new cars, which has a depressing economic and jobs impact. And, second, it impedes the replacement process – we call it the virtuous cycle - by which cleaner, more fuel efficient and safer vehicles are brought into the fleet.

So, the question is not whether our industry will continue to introduce and integrate these sophisticated vehicle innovations, but how quickly and deeply they penetrate the overall vehicle fleet due to consumer acceptance and purchases. Industry and government must continue to work collaboratively to ensure we fully maximize the benefits of these technologies while being cognizant that consumers may not be able to afford to purchase such a vehicle. After all, vehicles with great safety and environmental technologies that

get stuck in showrooms do little to advance the safety and environmental goals of policymakers.

This Committee should be commended for examining policies that will help spur, not hinder, technological innovation. For example, Chairman Murkowski's Promoting Critical Minerals Policy, S. 883, would help create a more secure domestic supply chain for critical minerals. The new generation of sophisticated and fuel-efficient vehicles is increasingly reliant on a variety of critical minerals and components. Ensuring affordable and reliable access to critical minerals is important to the continued success of the auto industry.

We have worked closely with Senators Stabenow, Peters and Alexander on the Vehicle Innovation Act, S. 1408, that the Committee also included in the Energy Policy Modernization Act of 2015, S. 2012. The Vehicle Innovation Act would promote investments in research and development of fuel-efficient and advanced safety technologies, such as V2V and V2I.

Finally, we support Senator Stabenow's efforts to expand the Department of Energy's Advanced Technology Vehicle Manufacturing (ATVM) program to allow medium- and heavy-duty truck manufacturers to qualify for loans under the program (S. 1449). Opening the ATVM loan program up to automotive suppliers has been successful; we believe affording the same opportunity to truck manufacturers will further advance our nation's goal of energy independence.

It is important to note that all of the aforementioned vehicle policies examined by this Committee are technology neutral. Automakers believe that effective energy policy must be based on broad, market-oriented principles. The market should be allowed to weigh variables like cost, quality, utility, reliability, and risk. Ultimately, consumers will decide which transportation solutions work best for them.

In closing, I would like to reiterate the excitement and innovation that characterizes today's auto sector – not just because of the record sales numbers for 2015 but also because of the tremendous performance, environmental and safety features that are being incorporated into vehicles available to consumers in showrooms across the country. Mobility has never been better.

Thank you again for providing me this opportunity and I look forward to answering your questions.

The CHAIRMAN. Thank you, Mr. Bainwol, very interesting.
Ms. Cullen, welcome.

STATEMENT OF GENEVIEVE CULLEN, PRESIDENT, ELECTRIC DRIVE TRANSPORTATION ASSOCIATION

Ms. CULLEN. Good morning, Chairman Murkowski, members of the Committee. I'm Genevieve Cullen, President of the Electric Drive Transportation Association, and I'm very pleased to be here today to speak to you about the advances being made in electric drive.

The Electric Drive Transportation Association is a cross industry trade association. Our members include the entire electric drive value chain that is developing, manufacturing and deploying vehicles and infrastructure of an electric drive fleet. Today electric drive is performing in light duty cars, trucks, buses and mobile equipment offering clean, high performing, affordable and efficient alternatives to oil.

Innovation throughout the industry value chain is providing consumers with even wider vehicle options with enhanced performance and at reduced costs. These advances are also accelerating transformational changes in mobility overall by connecting the power, transportation and communication sectors.

Since the commercial scale introduction of plug in vehicles in late 2010, this segment has grown exponentially from two vehicles to almost 40 battery and plug in hybrid vehicles for sale today are planned for roll out in the next model year. These vehicles include offerings across a range of price points, performance profiles and vehicle categories from economy to luxury with all electric ranges from 11 to 280 miles.

Total U.S. sales of plug in vehicles surpassed $400,000 in 2015, and global sales are expected to triple to $179 billion in 2024.

The diversity of the electric drive market is set to grow further with the addition of fuel cell electric vehicles which can offer approximately 300 miles of range and refueling in three to five minutes.

Over the past few weeks at auto and consumer electronic shows auto makers have showcased a large array of electric drive vehicles including a mid-priced battery electric vehicle with a 200-mile range and fast charge capability, a luxury plug in hybrid, a fuel cell electric crossover, a battery electric microbus and a plug in hybrid minivan. This is just a sampling of the headline catching vehicles but it illustrates the diversity of electric drive offerings and the diversity of customer needs they are designed to meet.

Behind the vehicles are innovations and investments throughout the supply chain that are enhancing performance and reducing the cost of batteries, fuel cells, components and materials.

A notable example is the reduction in the cost of lithium ion batteries which Senator Cantwell mentioned and as well as the reduction in automotive fuel cell costs in part from the private sector collaboration with the Department of Energy which has brought down those costs by more than 35 percent since 2008.

Innovation in electric drive extends beyond vehicles. Collaborations are occurring across the industry to drive down ecosystem costs and build out infrastructure.

Utilities are creating new business models with smarter demand management mechanisms to serve this mobile load and maximize the benefit of energy storage to the grid and to their customers.

Vehicle battery and energy companies are partnering to scale battery production and diversity energy storage options at the home and commercial scale.

Use of new and post automotive batteries for stationary storage gives energy consumers greater control of their energy choices, enhances grid stability and efficiency and in sports, the increased use of renewable and distributed energy.

At the same time vehicle charging facilities have also expanded greatly. There are a reported 12,000 public charging stations in the United States with 30,000 charging outlets. These numbers do not include private, residential and the fast growing number of workplace charging options available. Just as quickly business models are emerging to leverage hardware and software capabilities for diverse charging needs and locations.

Vehicle and phone-based applications as well as increased operability between charging facilities are making it easier for drivers to evaluate charging options and increase their electric miles traveled.

Hydrogen infrastructure is emerging along with last market fuel cell electric vehicles. In California nearly 70 stations are scheduled to open in the next few years. Public/private collaborations are moving forward to expand that number in California and other states.

Electric drive transportation is also reinforcing the autonomy of the in vehicles. While the continuum of the autonomous technologies being built into vehicles today, it's not exclusive to electric drive. Electric drives, in many ways, is the optimal partner as high visibility prototypes on the road today demonstrate.

Watching my clock, so I will wrap this up.

To summarize I will say that we are making great strides, but we are still an emerging market and we're pushing to deliver enhanced performance at reduced cost. Public/private partnerships throughout the value chain from technology to infrastructure build out are critical to speeding those innovations.

And we very much appreciate this Committee's recognition of that important work in S. 2012 supporting research, development and deployment work in cars and trucks at the Department of Energy.

Again, I thank you for the opportunity to speak with you today, and I look forward to your questions.

[The prepared statement of Ms. Cullen follows:]

TESTIMONY OF
GENEVIEVE CULLEN, PRESIDENT
ELECTRIC DRIVE TRANSPORTATION ASSOCIATION
BEFORE THE
SENATE ENERGY AND NATURAL RESOURCES COMMITTEE

JANUARY 21, 2016

Good morning, Chairman Murkowski, Ranking Member Cantwell and members of the committee. I am Genevieve Cullen, President of the Electric Drive Transportation Association and I am pleased to have the opportunity to speak with this committee about the important advances being made in in electric drive vehicles and infrastructure.

The Electric Drive Transportation Association (EDTA), founded in 1989, is the cross-industry trade association promoting the advancement of electric drive technology and electrified transportation. EDTA membership includes the entire electric drive value chain – including established and emerging vehicle, battery and component manufacturers, as well as electricity providers, smart grid and infrastructure developers.

Collectively, our membership is developing and manufacturing the vehicles and infrastructure of an electrified fleet. By using electricity to power hybrid, plug-in hybrid, battery and fuel cell electric vehicles, automakers can now offer drivers clean, high performing, affordable and efficient alternatives to oil. Electric drive vehicles provide documented benefits in emissions reduction and performance. Because the technology allows for flexibility in how these solutions are used across different vehicle platforms, manufacturers are able to meet the increasingly diverse operational demands of consumers and businesses. These solutions have been applied in light duty cars and trucks, buses, utility vehicles, medium- and heavy-duty transportation and mobile equipment, just to name a few electric drive vehicle options.

Drivers of electric vehicles are enjoying greater options, reduced costs and enhanced performance thanks to advances in vehicle and infrastructure technologies throughout the value chain. These advances are also accelerating transformational changes in mobility overall by connecting the power, transportation and communication sectors.

When the first mobile phone call was made in 1973, it would have been difficult for many to imagine how cellular technology would change not only the way we make telephone calls, but the manner and means by which we communicate. Today, electric transportation is poised to usher in a similar transformation of mobility. The devices that we drive will change the way we travel, how we consume energy and our methods of communication via the infrastructure that connects these segments.

Consumer Access to Vehicles

Since the commercial scale introduction of plug-in vehicles in late 2010, the electric drive segment has grown exponentially in little more than five years – from two to almost 40 battery and plug-in

hybrid vehicles for sale today or planned for roll-out in the next model year.[1] These vehicles include offerings across a range of price points, performance profiles and vehicle categories – from economy to luxury, with all-electric ranges from 11 to 280 miles.

The diversity of the electric drive market is set to grow further with the addition of fuel cell electric vehicles. Fuel cell buses have been providing zero emission transit and ground support options in the U.S. for years. In 2015, two fuel cell electric vehicles entered the commercial light duty vehicle market, including the Toyota Mirai, and the Honda Clarity will be offered in the U.S later this year. Fuel cell vehicles can offer approximately 300 miles of range and 5 minute refueling. California, which leads the nation is overall vehicle sales, reports projections that fuel cell electric vehicle fleet in the state will grow to 10,500 by the end of 2018 and 34,300 by the end of 2021. [2]

Total sales of plug-in vehicles in the U.S. surpassed 400,000 in 2015. Market research firm IDTechEx projects the global sale of hybrid and pure electric cars will triple to $178.9 billion in 2024 and recent auto shows reflect the aggressive investment of automakers in electric drive options for their customers.

At the auto shows in Detroit and Los Angeles, the Consumer Electronics Show in Las Vegas, and as I expect to continue at the auto show here in Washington, electric drive was on prominent display with automakers eager to show off their most recent advances in battery and other electric drive applications. Consumers are gaining access to cars with longer electric ranges, faster charging capability and greater connectivity.

Over the past few weeks, automakers have showcased a large array of electric drive vehicles – including a mid-price battery electric vehicle with a 200 mile range and fast charge capability, a luxury plug-in hybrid and fuel cell electric crossovers and a battery electric micro bus. This is just a sampling of the headline catching vehicles, but it illustrates the diversity of electric drive offerings and the diversity of customer needs they are designed to meet.

Beyond the exciting models that you can see at the auto show, auto manufacturers have ambitious goals for electric drive for the next five years, including expanded hybrid, battery electric, plug-in hybrid and fuel cell vehicle offerings and the substantial investments development investments needed to achieve them.

Innovation in Batteries and Energy Storage

These vehicle offerings reflect the innovations occurring throughout the supply chain that are enhancing the performance and reducing the cost of electric drive batteries, fuel cells, components and materials. The cost of lithium ion batteries has been reduced from an estimated $1000/kWh in 2008 to approximately $300 in 2016. Ongoing research and development in battery technology and cost reductions contribute to the positive outlook for this segment of the market. Navigant Research

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[1] Electric Car Insider 2015 Q4, electric-car-insider.com

[2] 2015 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development http://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2015.pdf

projects that the global market for lithium ion batteries will grow at a compound annual growth rate of 32% from 2015 to 2020. [3]

Private sector collaboration with the U.S. Department of Energy's (DOE) National Laboratories in fuel cell and hydrogen research and development have helped reduce automotive fuel cell costs by more than 35 percent since 2008 and by more than 80 percent since 2002. Fuel cell durability has doubled and the need for platinum has fallen by 80 percent since 2005.

Innovation in electric drive is not limited to vehicles. Vehicle manufacturers are forging new collaborative models to drive down ecosystem costs and build out infrastructure. Utilities are creating new business models with smarter demand management mechanisms to serve this mobile load and maximize the potential roles of automotive energy storage that micro-storage units can provide to the grid and to their customers.

Vehicle, battery and energy companies are collaborating to scale battery production and diversify energy storage options at the home and commercial scale. Automobile manufacturers are also working with utility and infrastructure partners to create a stand-alone energy storage systems that can be connected to or operate independently of the grid.

Expanding secondary uses provides an additional revenue stream in vehicle batteries and also enables wider adoption of renewable generation. Grid and distributed storage gives energy consumers great control over their energy choices and enhances grid stability and efficiency.

Expanding Infrastructure

Electric vehicle charging facilities have expanded rapidly in the last 5 years. DOE reports about 12,000 public charging stations with over 30,000 charging outlets and these numbers do not include private, residential and a fast growing number of workplace charging options. The charging segment – known as the Electric Vehicle Service Equipment or EVSE industry – is fast growing and diverse. Global revenue from the electric vehicle supply equipment sector is projected to grow to $5.8 billion by 2022.[i]

New entrants and partnerships are expanding driver options for charging using Level 1, Level 2, DC Fast Charge and wireless charging applications. Just as quickly, new business models are emerging to leverage hardware and software capabilities and satisfy diverse customer needs for charging locally, in commercial retails locations and on interstate highways. Vehicle manufacturers and EVSE companies are collaborating to expand charging infrastructure and utilities are investing in electric charging facilities to meet their customers' growing need for charging opportunities.

Meanwhile, hydrogen infrastructure is emerging alongside introduction of mass-market fuel cell electric vehicles. Today, the majority of hydrogen stations are in California, where nearly 70 stations are scheduled to be open in the next few years. Public/private collaborations in California and other states are moving forward with deployment of additional hydrogen infrastructure.

Access to electric charging is being further enhanced by vehicle and phone-based applications that make it easier for drivers to plan trips, evaluate charging options and increase their electric miles

[3] Navigant Research crowns LG Chem as the Li-Ion Leader, Charged, Issue 22 November/December 2015 p.13

travelled. Increased operability between charging facilities operated by different companies is also expanding consumer options and control over when, where, and how they charge their vehicles at home, work and on the road.

Autonomy and New Mobility Models

Electric drive transportation is also reinforcing the advance of autonomy in vehicles. While the continuum of autonomous technologies being built into vehicles today is not exclusive to electric drive vehicles, electric drive is in many ways the optimal partner, as high visibility prototypes, such as the Google concept, demonstrates.

Increased connectivity and autonomy are changing the way that we see and use mobility. In particular, personal mobility is expanding to include non-ownership and on-demand car use. Electric drive is optimized for the car-sharing paradigm, with electric ranges and efficient technologies, like regenerative braking, that are maximized during the urban driving that dominates this market.

Innovations in electric drive transportation that enhance performance and reduce costs are providing consumers, businesses and governments greater options while reducing emissions and diversifying the transportation sector's dependence on oil. The accompanying advances across the electric drive ecosystem, in infrastructure, energy management and connectivity are also remaking our relationship with mobility energy and connectivity.

Public Private Partnerships Speed Innovation

As detailed here today, electric drive technologies and the industries commercializing them are making great strides. We are also still an emerging market and pushing to deliver enhanced performance at reduced costs. Public private partnerships throughout the value chain- from technology to infrastructure build-out, are critical to speeding those innovations.

We appreciate this Committee's recognition of that important work in S. 2012, Energy Policy Modernization Act of 2015, which includes *Vehicle Innovation Act* provisions, establishing statutory authorization for the critical research, development and deployment programs at the Department of Energy. The potential to expand electric drive in the medium and heavy duty segment is great; the bill's support for DOE partnerships with industry will help to achieve the significant efficiency gains and emissions reductions that are possible in that segment.

Electric drive is already reinforcing innovation across the evolving mobility sector, which increasingly includes transportation, energy and communications. We have great expectations for expanding this innovation in the market and securing the economic, energy and environmental benefits that it provides for the nation.

Again, I thank you for the opportunity to speak with you today and look forward to your questions.

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[i] Navigant Research

The CHAIRMAN. Thank you, Ms. Cullen.
Dr. Gearhart, welcome.

STATEMENT OF DR. CHRIS GEARHART, DIRECTOR, TRANSPORTATION AND HYDROGEN SYSTEMS CENTER, NATIONAL RENEWABLE ENERGY LABORATORY

Dr. GEARHART. Chairman Murkowski and members of the Committee, thank you for the opportunity to speak today. I'm Chris Gearhart, Director of Transportation and Hydrogen Systems Research at the National Renewable Energy lab. Prior to coming to NREL I worked at Ford Motor Company for 16 years on, among other things, hydrogen fuel cell vehicles.

Innovation has always been an important part of the automotive industry, but today the rate of change is faster than ever. There are technologies on the horizon that promise a future with cars that don't crash, that don't damage the environment and they create new business opportunities we couldn't have imagined just a few years ago.

The Department of Energy and the national labs are working on technologies to help make this future a reality. And today I'd like to talk to you about just a few of the many ways the national labs are helping the automotive industry meet these goals while continuing to be the engine of our economy.

Connected and autonomated vehicles are all over the news. They're generally presented in the context of safety and convenience but they're also going to have a very big impact on energy and emissions. A group of researchers at NREL and at other national labs are starting to quantify these impacts.

One example of such research in this area is NREL's connected traveler project. This is an ARPA-E funded project with the goal to develop algorithms to understand a traveler's preference so that tailored recommendations and incentives can be provided to the individual traveler using real time data so they can make better transportation decisions. From this and other projects it's clear that big data and cyber security are going to be increasingly important in the automotive industry and the national labs have significant expertise and capabilities in these areas.

The labs are also doing lots of work to accelerate the development and deployment of electrified vehicles. We're using our expertise in lithium ion batteries, high performance computing and simulation to help the automotive industry shorten design time and improve the performance of automotive batteries. One great example of this is our CAEBAT project which is a project to develop new computer-aided engineering tools which the automotive industry can use to shorten design time for battery development.

Wide band gap semiconductor materials. These will make power electronic devices smaller, more efficient and able to operate at higher temperatures. For electric vehicles what this means is that we'll have more efficient vehicles and more efficient charging stations. Power America, sponsored by the DOE, is a partnership bringing together industry, universities and national labs to accelerate the development and commercialization of these devices.

Electric vehicles are also becoming part of the ever expanding Internet of everything. And at NREL we're examining these inter-

actions, the interactions between building energy systems, the utility grid, renewable energy sources and electric vehicles and we have world class facilities including the energy systems integration facility and the vehicle technology integration facility to study these interactions.

As has been mentioned a few times, fuel cell electric vehicles are now commercially available. This has been made possible, in no small part, but more than a decade of innovation supported by the Fuel Cell Technologies Office resulting in more than a 50 percent decrease in the cost of fuel cell systems. This is fantastic, but there are still significant challenges to be met including the cost effective generation of renewable hydrogen and the development of a robust hydrogen fueling infrastructure.

NREL is a world leader in renewable hydrogen production. We're also partners in H2 First, a collaboration with Sandia National Labs, that is working with industry partners to find innovative solutions to hydrogen infrastructure problems.

The internal combustion engine is going to continue to be an essential part of the transportation system, particularly for heavy duty transportation. Ground breaking research over the past 10 years has identified new combustion engine strategies that particularly when optimized to run on renewable fuels, will offer significantly higher efficiency and lower emissions. The DOE has launched an initiative coordinating the efforts of researchers across the lab system to work on this co-optimization of biofuels and engines.

Replacing heavy steel components with components made of lighter metals, plastics or composites can reduce vehicle mass by up to 20 percent which results in a 12 to 16 percent reduction in fuel consumption and greenhouse gas emissions. The Institute for Advanced Composites Manufacturing and Innovation, supported by DOE's Advanced Manufacturing Office, is working to develop new, low cost, high speed, efficient manufacturing and recycling process technologies for advanced polymer composites.

So in conclusion there's a wide range of research underway that will achieve many benefits for the nation's transportation system including improving energy efficiency, reducing environmental impact and driving U.S. competitiveness. These are very exciting times.

Thank you and I would be happy to address any questions.

[The prepared statement of Dr. Gearhart follows:]

Testimony of Dr. Chris Gearhart
Director, Transportation and Hydrogen Systems Center
National Renewable Energy Laboratory
before the
U.S. Senate Committee on Energy and Natural Resources
January 21, 2016

I would like to thank Chairman Murkowski, Ranking Member Cantwell, and the members of the Committee for the opportunity to speak about the status of innovation in the automotive industry. I am Chris Gearhart, the Director of Transportation Research at the National Renewable Energy Laboratory (NREL), the Department of Energy's primary laboratory for research and development of renewable energy and energy efficiency technologies. Prior to coming to NREL, I worked at Ford Motor Company in their Scientific Research Laboratory for 16 years. During my last six years at Ford, I led their Hydrogen Fuel Cell Vehicle research teams.

Innovation has always been an important part of the automotive industry, but today the rate of change is faster than ever. There are technologies on the horizon that promise a future with cars that don't crash, that don't damage the environment, and that create new and exciting business opportunities we couldn't have imagined just a few years ago.

The Department of Energy (DOE) and its national laboratories are helping bring about this future. In particular, we are putting the unique expertise and capabilities of our national labs to work on new technologies that will reduce emissions, and promote energy diversity and security. Today the transportation sector in the United States accounts for 72% of the country's petroleum use and about one third of the United States' greenhouse gas (GHG) emissions.[1] Of these emissions, cars and light-duty trucks contributed 57%, roughly 1.5 billion metric tons per year (1,514 MMT in 2005)[2]. Recent studies have shown that a portfolio of technologies could reduce domestic petroleum consumption in the light-duty transportation sector by 80% by 2050.[2,3]

My testimony today will focus on the role of technology supporting this vision in four areas:

- Connected and autonomous vehicles
- Vehicle electrification and integration with the electrical grid
- Hydrogen fuel cell vehicles and hydrogen infrastructure
- Efficient internal combustion vehicles operating on biofuels

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[1] Annual Energy Outlook 2013, EIA, 2013

[2] Transportation Energy Futures, EERE, 2013

[3] Transitions to Alternative Vehicles and Fuels, National Research Council, 2013

Connected Vehicles

In the very near future, cars and travelers will transmit and receive information from each other and from the rest of the infrastructure that makes up the cities and highways they move through. This connectivity creates the potential to optimize mobility, energy consumption, and dramatically reduces the risk of car crashes. This future is coming very quickly. Although not common yet, many new cars are Wi-Fi enabled. Two thirds of American's have smart phones. These smart phones are turning travelers into sensors that provide real time data about traffic conditions on our highways. Its clear that Big-data and cyber-security are going to be increasingly important as connected vehicles become more prevalent. The national labs have significant expertise and capabilities in these areas.

Initial studies by researchers at NREL and Oak Ridge National Laboratory attempt to assess the range of possible energy effects of connected and autonomous vehicles.[4,5] These studies find that there are potentially large energy effects, but that the magnitude of these effects are uncertain. Technology that enables autonomous vehicles is advancing quickly. This time of year—with the Consumer Electronics Show just over, the North American and International Auto Show in Detroit in full swing, and the Washington Auto Show starting tomorrow— the number of press releases related to autonomous demonstration and partnerships is astonishing.

Cars are becoming the next consumer electronics, and consumer electronics companies are getting into the car business. One interesting example of this is that NVIDIA, a company that traditionally makes graphics cards for gaming platforms, is casting itself as a supplier of computer chips for autonomous vehicles. Their argument is that autonomous vehicles will require rapid onboard computing power and that the computing tasks required to fuse data from multiple sensor platforms into a coherent representation of what surrounds a vehicle are very similar to the tasks required to render a realistic 3-D image based on a mathematical model generated by a computer game.

At the highest level there are three ways that connectivity and automation can impact energy and emissions. First, they can improve the efficiency of vehicle movement so that each mile driven requires less energy. Second, they could enable wider adoption of vehicles that use alternative energy and help to shift transportation energy to more renewable energy sources. Finally, these technologies, particularly self-driving cars, will remove barriers to driving—potentially increasing the number of miles driven dramatically.

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[4] A. Brown, J. Gonder and B. Repac, "An Analysis of Possible Energy Impacts of Automated Vehicles" , in Lecture Notes in Mobility, edited by G. Meyer and S. Beiker (Springer, City, 2014), pp. 137

[5] D. MacKenzie, Z. Wadud and P. Leiby: A First Order Estimate of Energy Impacts of Automated Vehicles in The United States, in 2014 TRB Annual Meeting, City, 2014

Connected vehicles that have information about various routes, traffic conditions, signal timing, and other factors impacting energy use can select the route that minimizes energy required at the wheels. If the vehicle is also a hybrid or plug-in hybrid electric vehicle, it may also be able to adapt the hybridization strategy to maximize the efficiency of the powertrain over that route. Vehicles that are both connected and autonomous can move in concert with each other, creating smoother traffic flow and reducing the amount of acceleration and deceleration when driving. Similarly, interactions among vehicles, traffic signals, and other infrastructure will optimize traffic flow in urban areas and reduce the amount of energy required for the same distance traveled. In long-haul trucks, connectivity and automation will allow trucks to form platoons and reduce energy consumption. An NREL study showed that at highway speeds, class-8 trucks could reduce fuel consumption by 6.4%. [6]

Connectivity may enable the use of alternative energy for transportation. Connected vehicles will know the location of the nearest compatible charging or fueling station. This potentially reduces some of the barriers to market penetration of these vehicles. Connected battery electric vehicles and plug-in hybrid vehicles can interact more directly with the electric grid. This may enable a deeper penetration of renewable electricity on the grid. Autonomous vehicles could self-drive to charging and fueling stations, returning fully charged when the driver needs them. This could increase the effectiveness of charging and fueling infrastructure, delivering the same benefits with fewer stations.

The greatest uncertainty associated with connected and autonomous vehicles is the impact these technologies will have on vehicle miles traveled. These technologies may make mobility more effective so that the same societal benefit can be achieved with fewer miles traveled. For example, connectivity enables ride- and car-sharing business models, such as Uber and Lyft, to have the potential to increase vehicle occupancy and mobility efficiency. It is also possible that these technologies will remove barriers to transportation access, which may increase the total number of miles driven. Presumably this would increase the mobility benefit to society, but it would also increase transportation energy use and emissions. Finally, with a fully autonomous vehicle, one can envision scenarios in which self-driving cars significantly reduce the cost of time lost while driving. This could promote greater urban sprawl and significant increases in miles traveled.

From an energy and emissions perspective, many of these effects are working in opposite directions. It remains to be seen which effect will be dominant. The Office of Transportation within the DOE's Office of Energy Efficiency and Renewable Energy is working with bringing together a consortium of national lab researchers to investigate the energy and greenhouse gas impact of these technologies. This

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[6] Lammert, M.; Duran, A.; Diez, J.; Burton, K.; Nicholson A. (2015). "Effect of Platooning on Fuel Consumption of Class 8 Vehicles Over a Range of Speeds, Following Distances, and Mass." NREL/CP-5400-62348 http://www.nrel.gov/docs/fy15osti/62348.pdf

effort is examining the nexus of energy and mobility for future transportation systems. Initial research will focus on connected and automated vehicles, urban science, decision science, multi-modal transport, and integrated vehicle-fueling infrastructure systems.

The effort will support robust analytical and foundational efforts to define and frame opportunities in this space and inform future activities across DOE's transportation technology portfolio.

One example of research in this area that we are doing at NREL is an ARPA-e funded project called The Connected Traveler: A Framework to Reduce Energy Use in Transportation. For this project, NREL and our partners will create a network architecture that approaches sustainable transportation as a dynamic system of travelers and decision points, rather than one of vehicles and roads, in order to create personalized energy-saving opportunities. The project will use currently available transportation data from an urban U.S. city, as well as simulated data based on real-time and demographic information. The goal of the project is to develop algorithms to understand a traveler's preferences, tailor recommendations to the user, and identify personal incentives that will enable transportation system energy benefits.

Vehicle Electrification

Battery electric vehicles (BEVs) have the greatest potential to reduce vehicle energy consumption. BEVs convert about 60% of the energy from the electric grid to power at the wheels. For internal combustion vehicles this is closer to 20%.[7] This means that BEVs use only about one third as much energy per mile driven as conventional vehicles. Yet significant challenges to widespread deployment of battery electric vehicles remain. Chief among these are cost, energy density, recharge time, and charging infrastructure.

Because of the low energy-density of batteries, the distance a BEV drives on a single battery charge is considerably less than that possible on a typical tank of gasoline. Even with a large penetration of mass-market 200-mile range electric vehicles, such as the Chevy Bolt and the Tesla Model-3, it will be difficult to electrify all of the vehicle miles traveled. Most vehicle trips are short enough that electric vehicles have sufficient range to make these trips, even with current battery energy densities. Although short trips account for most of the trips taken, long trips account for a disproportionate fraction of the miles traveled, and the range of BEVs is not sufficient for these trips. Presumably, these additional trips will still be taken, just not in an electric vehicle. This sets up a dilemma for electric vehicle drivers. If batteries are small, they are inexpensive, but will electrify fewer of the driver's trip needs. As batteries get bigger, they will electrify more of the driver's trips, but at a higher marginal cost. These two competing effects will likely limit the number of

[7] https://www.fueleconomy.gov/feg/evtech.shtml

miles electrified. This effect is mitigated somewhat with plug-in hybrid electric vehicles. With these vehicles, the range limitations will not be a problem, but there will still be a limit to the number of miles that are electrified.[8]

The national labs are using their expertise in Li-Ion battery chemistry, high performance computing and simulation to help the automotive industry to shorten design time and improve the performance of automotive batteries. One example is the Computer-Aided Engineering for Electric-Drive Vehicle Batteries (CAEBAT) project. CAEBAT is accelerating the development of and lowering the cost of lithium-ion (Li-ion) batteries for next-generation electric-drive vehicles by developing new computer aided engineering tools for battery development.

Wide-band gap semiconductor materials allow power electronic devices to be smaller, more efficient and operate at higher temperatures than silicon based power electronics. This has the potential to further increase the efficiency of BEVs. The fact that these devices can operate at higher temperatures may also reduce the size of the cooling system required. The Next Generation Power Electronic Institute is a DOE-sponsored Manufacturing Innovation Institute that is bringing together 18 companies, five universities and two national labs to form a center of excellence in the development of wide-band gap semi-conductor devices.

Wireless charging is likely for next generation electric vehicles. In addition to convenience for consumers, wireless charging provides a mechanism for connected and autonomous vehicles to connect to the energy grid more directly. This is one of the ways that connected vehicles could access more sustainable energy.

Hydrogen Vehicles

Fuel Cell Electric Vehicles (FCEVs) fall between BEVs and internal combustion vehicles on the efficiency spectrum. They are about twice as efficient as conventional gasoline ICE vehicles.

Perhaps the most exciting development in FCEVs is the commercial introduction of the Hyundai Tucson and Toyota Mirai and the launch of the new Honda Clarity later this year. The commercial introduction of fuel cell vehicles has been made possible by more than a decade of innovation, supported by the DOE's Fuel Cell Technologies Office (FCTO), resulting in a more than 50% decrease in the cost of fuel cell systems. Projected fuel cell system costs have dropped from $124/kWh in 2006 to $53/kWh in 2015.[9]

Of course there are still significant challenges to be met, including cost-effective generation of renewable hydrogen and development of a robust hydrogen-fueling

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[8] M.A. Tamor, C. Gearhart and C. Soto: A statistical approach to estimating acceptance of electric vehicles and electrification of personal transportation Transportation Research Part C: Emerging Technologies. 26, 125 (2013).

[9] DOE Hydrogen Program Record 15015

infrastructure. NREL is actively involved in all aspects of the DOE's hydrogen and fuel cell research portfolio.

Hydrogen Fueling Infrastructure Research and Station Technology (H2FIRST) is a project launched by the FCTO within the Office of Energy Efficiency and Renewable Energy. This project leverages capabilities at the national laboratories to address the technology challenges related to hydrogen refueling stations. Led by Sandia National Laboratories and NREL and supported by a broad array of public and private partners, the H2FIRST project is a strong example of DOE's efforts to bring national lab capabilities and facilities to bear on both immediate and mid-term challenges faced by industry. H2FIRST was established by DOE's FCTO directly in support of H2USA, a public-private partnership co-launched by DOE and industry in 2013.

The Hydrogen Infrastructure Testing and Research Facility (HITRF) at the DOE's Energy Systems Integration Facility is an important part of the H2FIRST project. It consists of hydrogen storage, compression, and dispensing capabilities for fuel cell vehicle fueling and component testing.

The HITRF is the first facility of its kind in Colorado and will be available to industry for use in research and development activities. In addition to fueling fuel cell electric vehicles, the HITRF will serve as a proving ground for component, system, and control testing. The facility is representative of current commercially available hydrogen fueling stations, enabling NREL to validate current industry standards and methods for hydrogen fueling as well as perform testing for next-generation technology and controls.

Other examples of fuel cell innovations coming out of NREL are in renewable hydrogen production and hydrogen energy storage. Hydrogen can also enable intermittent renewables. NREL has demonstrated hydrogen production from water using solar and wind power. The hydrogen is then stored and used in fuel cells to provide power during off-peak hours when there is no wind or sun. NREL is also a world leader in the direct conversion of sunlight to hydrogen without the need for the intermediate step of power production and will continue to focus on much-needed advances.

Biofuel vehicles

Finally, I would be remiss if I didn't talk at least briefly about innovations related to the internal combustion engine. Although electrified vehicles will become increasingly important in the future, internal combustion engines will remain an essential part of the transportation system, particular for heavy-duty transportation. The DOE and the national labs are working on multiple research areas to improve the efficiency of internal combustion engine vehicles and the development of advanced biofuels to reduce the emissions impact of these vehicles.

One area that is particularly exciting is ongoing research lead by the DOE to investigate the potential to co-optimize engines and biofuels to make the most efficient biofuel-engine system.

More energy-efficient and environmentally friendly vehicles call for simultaneous increases in powertrain efficiency and reductions in emissions, requiring substantial advances in internal combustion engines. In turn, advances in engine combustion rely on a thorough understanding of fuel properties, especially ignition kinetics behavior. By focusing on the intersection of fuel's physical and chemical properties, ignition kinetics, combustion, and emissions, NREL is supporting coordinated development of biofuels, advanced petroleum-based fuels, and advanced combustion engines.

NREL's combustion R&D bridges fundamental chemical kinetics and applied engine research to investigate how new engine technologies can be co-developed with fuels and lubricants to maximize energy-efficient vehicle performance. Researchers examine what happens to fuel inside the engine, how fuel interacts with equipment, and what emissions are produced. The results from and tools developed by the lab guide engine manufacturers in developing equipment and controls.

The DOE has launched an initiative, jointly funded by the Vehicle Technologies Office and the Bioenergy Technologies office, coordinating the efforts of more than 100 expert researchers across the national lab system to advance the goal of co-optimizing fuels and engines. This team will build on decades of remarkable advances in both fuels and engines. Groundbreaking research over the past 10 years has identified new combustion engine strategies that, especially if optimized to run on new fuels, would offer significantly higher efficiency and produce lower levels of engine-out pollutants than current engines. At the same time, research is advancing low carbon fuel options that can blend with petroleum-based feedstocks to significantly reduce GHG emissions and enable engine performance gains.

The confluence of these developments provides a rare opportunity to introduce co-optimized new fuels and engines that can achieve dramatic performance improvements at the enterprise level. Specifically this initiative targets a 30% reduction in per-vehicle petroleum consumption beyond the levels to be provided by the expected evolutionary, policy-driven improvements to today's fuels and engines. This 30% improvement reflects two contributions – efficiency and displacement. The efficiency improvement reflects fuel consumption reductions possible through introduction of new fuels that allow engines to operate at their maximum efficiency, freed from the constraints imposed by current fuels. While the engine of 2030 is expected to be more efficient that today's, we expect that new fuels could allow an additional 7-15% reduction in fuel consumption. The second contribution reflects displacement of petroleum through the introduction of 16 billion gallons of advanced biofuels by 2030.

Another important topic that doesn't fit into any of my four categories, but will have significant impact on fuel-economy is innovation in the area of light-weight materials. By replacing heavy steel components with components made of less dense metals, plastics, or composites, it is estimated that vehicle masses can be reduced by up to 20%, resulting in a 12%–16% reduction in fuel consumption and a similar reduction in GHG emissions. Larger mass reductions may be possible, but will require the wide spread adoption of active crash-avoidance technologies.[10]

The Institute for Advanced Composites Manufacturing and Innovation (IACMI), supported by the DOE's Advance Manufacturing Office and lead the University of Tennessee, will work to develop new low-cost, high-speed, and efficient manufacturing and recycling process technologies that will promote widespread use of advanced fiber-reinforced polymer composites. IACMI will focus on lowering the overall manufacturing costs of advanced composites by 50 percent, reducing the energy used to make composites by 75 percent, and increasing the ability to recycle composites by more than 95 percent within the next decade.

In conclusion, these are very exciting times for the automotive industry. The OEMs are coming out with new technology at an unprecedented rate. The DOE's national laboratories have unique world-class research capabilities that can help the automotive industry meet critical fuel-economy and emissions objectives. It is clear that the range of research now underway for these rapidly evolving technologies will achieve many benefits for the nation's transportation system — while improving energy efficiency, lessening environmental impacts, driving U.S. competitiveness, and providing all of us with more and better options for the mobility on which we all depend. These are exciting times.

Thank you. I would be happy to address any questions.

[10] N. Lutsey, "Review of techical literature and trends related to automobile mass-reduction technology)

The CHAIRMAN. Thank you, Dr. Gearhart.
Mr. Mosquet, welcome.

STATEMENT OF XAVIER MOSQUET, SENIOR PARTNER AND MANAGING DIRECTOR, THE BOSTON CONSULTING GROUP

Mr. MOSQUET. Thank you, Chairman Murkowski and the members of the Committee for the opportunity to testify today.

Innovation is clearly increasing in the automotive industry. OEM R and D spending has increased by eight percent per annum since 2009, and the supplier spending has increased by five percent. And interestingly our consumer surveys show that customers want to buy cars from car manufacturers who bring new technologies to market.

We see today five areas of spending and patent filing for car manufacturers and suppliers today. It's power trains, including electrification; it's light weighting; it's connectivity; it's active safety; and then, autonomous driving. These innovations are fueled by regulation, by customer demand, but also by technological advancements.

If I look at the power train evolutions there's three areas. One is internal combustion engines. The other one is hybrids and battery electric vehicles, and the next one is fuel cells.

In internal combustion engines, we've seen many improvements. Right now, all the evolutions seeing you a low friction, advanced injection, advanced new cooling and others have bringing you efficiency improvements from 2009 to 2020 by 35 percent to 50 percent reduction of fuel efficiency and emission roughly at a cost of $2,000 to $2,500 per car. And this is why we see today a landscape and that will continue for the foreseeable future where naturally these technologies will present the vast majority of the market.

Meanwhile, the market for hybrids and battery electric vehicles is being challenged. Right now this market has been growing for ten years and peaked in 2013 at 3.8 percent penetration of the U.S. market and the penetration declined to 2.9 percent last year.

The challenge is only six percent of the U.S. drivers are ready to pay more for a greener and more efficient car. And what they want to spend, on average, is $4,600. So that creates an unstable market for hybrids and is well below the cost of either battery electric vehicles and fuel cells.

What this means is the support from the legislator in the form of incentives will have to remain potentially below the current cap of 200,000 vehicles per OEM and then support for charging and refueling infrastructure will be needed for this market in the next few years.

On light weighting, it's commonly agreed that about ten percent of weight reduction would help gain six to eight percent fuel efficiency on each car at a cost of $2 to $5 per pound saved. The materials are aluminum, magnesium, advanced steel, carbon composite, of course. And there's two challenges there for innovation.

One is the availability of some of this materials. It's particularly true for advanced steel and maybe for the cost of carbon fiber which I know the Committee has been very active on.

The other thing is now OEMs and you will all agree that they're picking the right material for each different parts of the car is

what needs to happen and then bonding technologies will be a main source of innovation.

Connectivity includes two areas. One is 4G LTE. I would say this is happening with natural market development. But the other one is vehicle-to-vehicle, vehicle-to-pedestrian, vehicle-to-infrastructure, which we're required a minimum adaption to give the benefits both in terms of safety and in terms of traffic regulation. And there they will be a need for further regulation for this market to develop naturally.

Active safety features today that are available with existing technology have the potential to reduce by 30 percent the number of accidents on U.S. roads and the number of fatalities. We think the benefit is about $250 billion every year to the U.S. economy. The challenge is today those features cost about twice more than customers are naturally willing to pay; therefore, penetration is low, single digits and only going at a few percent per annum.

Whereas, with more support, with a 50 percent penetration, the cost would decrease by two and there would be a naturally sustainable market. There will be need there for further innovation and also for more support to increase the penetration through customer education, potential incentives and more regulation.

Autonomous vehicle, which is the next step after active safety, has the promise to reduce the number of accidents by 90 percent and therefore, to reduce congestion and to improve the fluidity of the traffic.

Furthermore, we think that in dense urban environments we could replace, with a share of automated cars, we could replace roughly 900,000 private cars in New York, for instance by 19,000 shale vehicles which reduces the number of cars on the road, improves traffic and has significant impact not only on safety but also on fuel efficiency. And therefore there's a major challenge now to get to these as soon as possible.

Overall these technologies truly deserve the attention of the legislator—there is an important balancing act to think about where to spend, not only for the legislator, but also for the consumers as many of these technologies today still cost more than the consumer would be naturally willing to pay.

[The prepared statement of Mr. Mosquet follows:]

Xavier Mosquet
Senior Partner and Managing Director
The Boston Consulting Group

Testimony presented before the Senate Committee on Energy and Natural Resources
Hearing date: January 21, 2016

Accelerating pace of innovation in automotive

Today, automotive companies from around the world are competing on a global scale to bring new brands, models, features, technologies, and processes to market first. Innovation hit the brakes briefly in the wake of the 2008 global financial crisis, but our research and experience show that the pace of innovation accelerated again through 2013, and it is continuing as we enter 2016. Indeed, the recent and prospective developments in five key areas—powertrain, lightweight materials, connectivity, active safety and autonomous driving—may well herald a new golden age of technological advancement and automotive innovation.

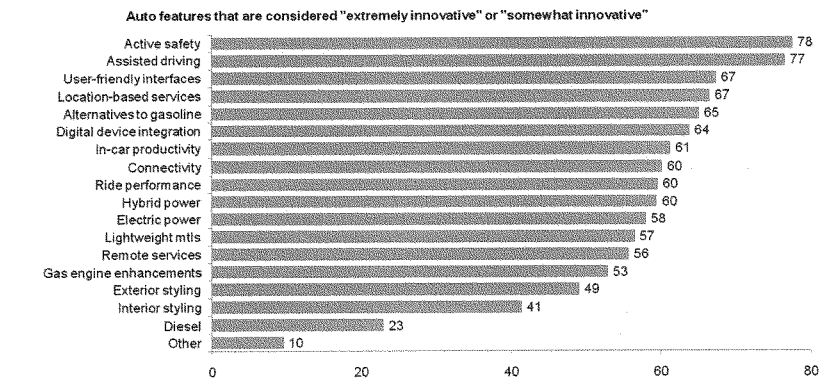
Driving these improvements is an intensified focus among automakers and their leading suppliers on introducing new technologies faster, continuing to improve fuel economy and reduce emissions, and developing important connectivity and active-safety features (including autonomous driving). Enabling these efforts is the transformation of the car from a collection of mechanical and hydraulic systems to a machine predominantly controlled by electronics and software. Together, these changes are altering the way cars are conceived, designed, manufactured, serviced, and driven.

Research from The Boston Consulting Group shows that consumers cite innovation[1]—both generally and in key areas such as connectivity, safety, and fuel economy—as an important consideration in their purchase decision. Our analysis indicates the following:

- Consumers want to buy cars from companies that bring new technologies to market.
- Connectivity and safety are important to consumers; they want to see innovation in these areas as well as in improving fuel efficiency (see exhibit 1).
- Consumer and regulatory concerns about oil prices, oil dependency, and global warming will ensure that technologies related to fuel efficiency and emissions reduction remain at the top of OEMs' research agendas.
- OEMs and suppliers will need to expand their R&D capabilities in electronics and software. Start-ups and technology companies also now invest significantly in the industry.
- Tier one suppliers are becoming increasingly important in bringing innovations to market.
- In areas like fuel efficiency and active safety, there is a potential gap between the cost of technologies and customers' willingness to pay.

[1] The Boston Consulting Group. *Accelerating innovation: new challenges for automakers.* Detroit, MI: BCG Report (2014). Retrieved from https://www.bcgperspectives.com/content/articles/automotive_innovation_accelerating_innovation_new_challenges_automakers/

Exhibit 1 | Active Safety and Assisted Driving Top the List of Innovative Features



Source: BCG Consumer Survey, October 2013.

R&D spending by OEMs has accelerated, increasing at a rate of 3 percent a year from 2001 through 2012 and at an annual rate of 8 percent since 2009. At tier one suppliers, R&D spending has risen by 4 percent a year since 2001 and by 5 percent a year since 2009. Another measure of innovation, the number of patent filings, also reflects an increase. The patent activity of tier one suppliers has outpaced that of OEMs for the past 15 years, with the number of filings increasing by 6 percent a year from 1995 through 2011, compared with a rise of 3 percent a year for OEMs.

Key Areas of Innovation

Three principal forces are driving innovation in the auto industry today: regulatory mandates with respect to fuel efficiency, emissions, and safety; consumer demand and expectations; and technological advances that enable the development of new features and reduce their cost. The result is that companies are concentrating their product-development efforts in five areas: powertrain, lightweight materials, connectivity, active safety and autonomous driving.

Our analysis of recent patent activity supports this view. Patent filings by the top OEMs on BCG's list of the most innovative companies, as well as by the biggest tier-one suppliers, show double-digit growth from 1995 through 2011 in powertrain, lightweight materials, and connectivity, compared with an average growth rate for all patent filings by these companies of only 4 percent. The number of patent applications in the area of active safety grew by 6 percent annually.

Powertrain and Electrification

Current fuel efficiency standards mandate an average fuel economy of 54.5 miles per gallon (mpg) in the United States for the 2025 model year; the European Union is targeting 64.8 mpg by 2020; and China's goal is 50.1 mpg by 2020. Automakers have stepped up the development of electric and hybrid vehicles and increased their efforts to improve the mileage of mass-market models through advancements such as more efficient powertrains and lighter car bodies. Some 50 automotive models offer hybrid engines today, up from only 2 in 2001.

Conventional Internal Combustion Engine (ICE) technology is going through an evolution, providing significant potential for increased efficiency, improved fuel economy and reduced emissions. Ongoing research and development in fundamental engine processes (e.g. air handling, fuel injection, combustion, etc.), advanced computing capabilities, sensor technology and adoption of advanced manufacturing processes help accelerate the path toward mass commercialization of highly efficient ICEs for passenger and commercial vehicles.

Ongoing developments in ICE technology will help OEMs improve fuel economy of gasoline-fueled vehicles by up to 35 to 50 percent (30 to 35 percent for diesel fueled vehicles) between 2009 and 2020[2] at a cost of $2,000 to $2,500 to consumer per vehicle. These improvements will ultimately help OEMs meet emission targets.

Among the recent developments in ICE technologies, low-temperature combustion (LTC) is noteworthy due to very high thermal efficiencies and significant emissions reduction potential through optimization of fuel injection, fuel mix and combustion reaction properties.

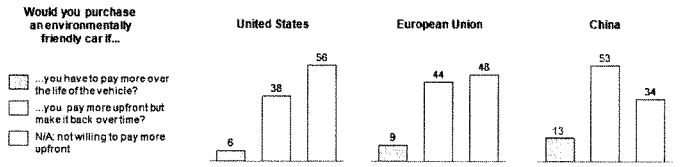
In addition to LTC, there is a wide range of advancements in ICE system level technologies for gasoline-fueled ICEs including optimized cooling, low friction materials, air handling (e.g., optimized air intake and exhaust, variable valve timing, turbo chargers), advanced combustion (e.g., high compression ratio, GDI, EGR) advanced fuel injection, start/stop systems, engine downsizing and solid state energy conversion (e.g., conversion of exhaust energy into electricity).

Some of these developments, such as optimized cooling, low friction, start-stop systems, and engine downsizing combined with mild turbo charging, stand to see widespread adoption across many vehicle segments due to their relatively low cost. Other developments such as LTC require further R&D and technology maturation before they can be mass commercialized. Strong collaboration among industry, academia, research institutions and governmental and regulatory bodies will help overcome technical barriers and accelerate deployment of these technologies in commercial production.

Given these improvements, Internal Combustion Engines will continue to dominate for the foreseeable future. According to recent market forecasts, ~90% (~99% including hybrid and plug-in- hybrid) of global vehicle production in 2020 will still utilize some form of ICE (e.g. gas, diesel, LPG, CNG) as its source of power generation.

The penetration for hybrid and electric vehicles in the U.S. has been consistently growing in the past ten years and peaked at 3.8% of vehicle sales in 2013. In the past two years, it has declined to 2.9%, due to the cheaper price of gasoline. This is due to the fact that only 6.0% of U.S. customers are willing to pay more ($4,600/car on average) for a more environmentally friendly car without payback. Another 38% of customers are willing to pay on average $3,900/car[2], but they require a payback of less than three years on their investment. As prices of gasoline decline, the payback period of hybrid vehicles becomes too long. We note that another 56% of customers will not spend any more on their car for fuel efficiency or lower emissions (see exhibit 2).

Exhibit 2 | 6% of US and 9% of EU consumers are willing to pay more over the life of the vehicle for green cars; ~50% are unwilling



	United States			European Union			China		
Average upfront premium willing to pay ($)	4,600	3,900	0	5,400	3,800	0	5,800	3,700	0
Average premium willing to pay over vehicle life (%)	10	-	-	11	-	-	18	-	-
Average required payback (years)	-	2.9	-	-	3.0	-	-	2.5	-

Source: BCG Consumer Barometer March 2011, N = 1,027 in US, N = 5,016 in Europe; BCG Automotive Survey of car owners and intenders in China N = 550

[2]The Boston Consulting Group. *Powering autos to 2020: the era of the electric car?* Detroit, MI: BCG Report (2011). Retrieved from https://www.bcgperspectives.com/content/articles/automotive_energy_environment_powering_autos_2020_era_electric_car/

This constitutes a challenge for electric vehicles. Overall battery costs have declined significantly, due to technology and manufacturing improvements as cost at the cell-level have plummeted from roughly $700/kilowatt hour[3] in 2009 to $150/kWh today[4]. This translates to roughly $250/kWh at the pack-level. To provide a 200 mile range, which seems to be what customers are asking for to take care of range anxiety, battery powered electric vehicles (BEV) will need at least 50 kWh, representing an additional cost of $12,500/car today at the pack-level, and possibly $9,000/car in 2020, before any markup from the car manufacturers. Given this expectation, it is important that tax incentives or other forms of incentives remain in place to sustain this emerging market. Non-financial incentives like reserved parking spaces at charging stations or access to priority lanes are also strong purchase motivators in urban environments. Even with these extended ranges, fast-charging infrastructure on highways will remain necessary for battery powered EVs to support all driving needs.

In addition, small-scale series manufacturing of fuel cell electric vehicles (FCEV) has already started (e.g. Hyundai Tucson iX35, Toyota Mirai) and several other OEMs (e.g. GM, Honda, Ford, Nissan) have already announced their plans to launch FCEV by 2020. Recent studies forecast that FCEV production volumes will be in the range of 1,000–10,000 units p.a. per OEM in the next 5–10 years.

Current and forecasted technological progress coupled with experience curve and scale effects, are expected to reduce Fuel Cell System cost by 3%p.a. in the next five years. Fuel cell system costs are currently at $475/kW for a 50kW system (at 1,000 units production volume) and ~50% of system costs are driven by the Fuel Stack, which uses Platinum (Pt) as the reaction catalyst, exposing system costs to fluctuations in Pt prices. Our market models show that increasing scale and associated experience will further push system costs down (e.g. $295/kW at 10,000 units and $110/kW at 150,000 units of production) and by 2030 FCEV could reach similar levels of cost competitiveness (TCO) as BEV, if necessary investments are put in place to increase production capacity and hydrogen fueling infrastructure to support the development of the market.

The future of FCEV market is still subject to several tipping points that might limit the market to niche application. Alternative technology breakthroughs in BEV that can overcome current range/charging time limitations, insufficient hydrogen fueling infrastructure development (due to lack of long term commercial attractiveness) and unfavorable developments in cost structure can hamper projected growth trajectory. We believe the support of policy makers, regulatory authorities, together with a strong collaboration among industry and academia, is key to spur the development, of the future FCEV market.

Lightweighting

Lightweighting can be a major contributor to meet future vehicle efficiency requirements. It is generally accepted that a 10% reduction in vehicle mass can enable a 6-8% improvement in fuel economy of a vehicle with conventional Internal Combustion Engine.

Reducing mass also has a "compounding" beneficial effect. Firstly, reduced mass of the body structure can allow the use of smaller and lighter engines and smaller, lighter chassis components such as suspensions and brakes. Secondly, the decreased weight and resultant increased fuel efficiency can enable the vehicle to get the same range with less gas, thereby allowing the vehicle to haul less fuel and use smaller (lighter) fuel tanks. Finally, reducing weight of components can also allow manufacturers to offset weight gains that are the result of revised safety requirements or the addition of popular comfort and convenience features demanded by today's consumers.

The shift to lightweighting has several challenges around costs, manufacturability and serviceability. The material and processing costs of light weight materials (e.g. Aluminum, Advanced High Strength Steel (AHSS), Magnesium, Carbon Fiber Composites, etc.) are generally higher than that of current incumbent/conventional materials. In primary applications, the relative costs of lightweight materials are 1.2 to 5 times more than that of conventional materials. The ability to robustly manufacture (e.g. form and join) advanced materials is also another challenge in using lightweight materials. Simple techniques (e.g., welding, bolting, bending, stamping) cannot be used to join these new materials without compromising their strength, dimensional stability and durability.

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[3] The Boston Consulting Group. *Batteries for electric cars: challenges, opportunities, and the outlook to 2020.* Boston, MA: BCG Report (2010). Retrieved from https://www.bcg.com/documents/file36615.pdf

[4] General Motors Corporation.. *Global business conference - October 2015.* Detroit, MI:

Lightweighting materials with all the desired properties do not yet exist and must be developed. For instance, to reduce the cost of Carbon Fiber Composites, lower cost precursor materials are being explored and OEMs and steel suppliers are pursuing a new, 3rd generation of AHSS, that is affordable, with high strength and ductility.

Due to the aforementioned limitations and challenges around costs, manufacturability and availability, OEMs and their suppliers embrace a philosophy of picking the right material for the right place so that a number of different lightweighting materials are used for different applications. For example, Aluminum castings are ubiquitous in powertrain applications, such as engines and transmissions. Aluminum is also being used in structural members (e.g., Ford F150) of automobiles since the body structure holds the potential for the greatest mass reduction. Carbon Fiber Composites are also utilized for very demanding applications or where performance justifies its use, such as in high performance cars (e.g. Chevrolet Corvette, BMW i8).

The development of lightweight materials that break compromise of cost and resistance, as well as new bonding technologies and their related manufacturing investments, will justify the support of public policy.

Connectivity and Cyber Security

Automotive market is witnessing an unprecedented rise in connectivity. Most car manufacturers now offer embedded connectivity solution (such as GM OnStar) on most vehicles, 4G LTE hotspots as well as support brought in connectivity from smart phones (CarPlay, Android Auto). Over the next 10 years, penetration of embedded as well as brought-in connectivity support in new vehicles sold in the US is expected to reach close to 100%. In addition to rise in connectivity through embedded and brought in devices, increasing number of vehicles will connect to Wi-Fi networks to allow remote update of automotive software when needed. The benefits to the consumers and car manufacturers are high: accident or theft alert, remote unlocking, over-the-air updates of software, and better management of recalls and maintenance are among them.

In addition to being connected to the cloud, vehicles will connect with other vehicles, infrastructure and pedestrians through Dedicated Short Range Communication (DSRC) or V2X mainly to improve the range of vision of the car in order to increase safety, paving also the way for autonomous cars.

Increasing connectedness of cars to other devices and internet might make vehicles vulnerable to hacking attacks. Recent attempts by ethical hackers to expose vulnerabilities and extent of vehicle control that can be taken over by hackers has highlighted the need for strengthening cyber security in connected vehicles. We see cyber security as a key area automotive industry will remain focused on for next 5-10 years.

Active Safety

In 2014, the number of accidents on U.S. roads amounted to 6 million, causing 3.9 million injuries and 33 thousand fatalities. The cost to society of these accidents has been evaluated to $910 billion each year in the U.S. In addition to the pure safety dimension, every accident is usually the cause of traffic congestion, leading to increased fuel consumption.

Available Advanced Driver Assistance Systems (ADAS) that can be purchased today could help reduce the number of accidents on U.S. roads by 30%[5]. Those features include systems like forward collision warning and automated emergency braking, blind spot detection, and support to night vision. However the penetration of those features is low today, typically in the single digit percentage, and growing very slowly. Penetration is limited by the fact that customer willingness to pay is on average 50% of the current price of these features on the market. Given the value of scale in these technologies, their costs could be half of what they are today, with 50% penetration.

[5] Motor and Equipment Manufacturers Association & The Boston Consulting Group. *A roadmap to safer driving through advanced driver assistance systems.* Detroit, MI and Washington D.C.: BCG Report (2015). Retrieved from https://www.bcgperspectives.com/content/articles/automotive-roadmap-to-safer-driving-through-advanced-driver-assistance-systems/

The savings that are associated with the increased safety could be as high as $16k per car over the 20-year lifetime of the vehicles. There is therefore significant benefit to society, both in terms of safety and fuel-efficiency, to support the increased penetration of active safety features. This can be done through increased customer education, advancements in regulation as NHTSA recently announced, and potential incentives either from insurance companies or possibly tax incentives. The increase in penetration of ADAS is even more important as several of its sensor technologies, like cameras and LIDAR, can be the basis for future autonomous vehicles.

Autonomous Cars

Autonomous cars have the promise of significant benefits in terms of safety, convenience, fuel-efficiency, as well as lower emissions. Their evolution will likely come in stages, starting with partial autonomy, such as single-lane highway driving, adding features such as automated valet parking, and traffic jam autopilot. At some point, cars should be able to evolve at low speed in urban traffic, and then become fully autonomous in most driving conditions and speeds. Our analyses show the cost of these features to range from $4k for one feature to $10k for full autonomy at the time of market introduction.

Overall, customer demand for autonomous features and vehicles is very high, with 55% of U.S. drivers likely to consider buying a partially autonomous vehicle, and 44% a fully autonomous one[6]. 20% of these drivers are also willing to pay an extra $5k or more for autonomous driving features, showing the high value that customers place in the promise for increased safety, the convenience, and also the customer view that it could reduce their insurance and fuel expenses.

The safety impact when fully deployed should be significant, with a 90% reduction in the number of accidents, and therefore an increase in traffic fluidity and fuel efficiency. It is also noted that smoother driving improves fuel-efficiency, and better information on availability and location of parking spaces will further improve efficiency. In dense urban environments, up to 30% of time in a vehicle can be spent looking for a parking space.

In addition, our calculations show that with a shared fleet of robo-taxis, cities like New York could replace a fleet of 900k private vehicles by 80-100k shared cars, with the potential upside of more fluid traffic and significant fuel efficiency benefits. At the same time, these cars are less involved in accidents or do it at a much reduced speed, therefore it would be possible to reduce the weight of the vehicles with further improvement in fuel efficiency and reduced emissions.

Car sharing and connectivity can together increase the possibility of efficient carpooling, with a much higher mileage than privately owned cars, shared cars can significantly reduce the payback period of fuel efficient technologies and electric vehicles. A recent survey conducted by BCG and the World Economic Forum showed that 66% of customers in large cities would expect autonomous vehicles to be either hybrid or electric.

Supporting future market development

The automotive industry is experiencing a period of increased innovation, with significant potential impact on energy savings, health, safety and convenience for consumers. Many of these technologies will also add cost to current vehicles, at least in the short-term while technology and cost are being improved. In technologies related to fuel efficiency and safety, customers' current willingness to pay is often below the cost of bringing these technologies to market. During this period, there are several levers that legislation and regulation can pull to support the market development:

- Supporting the cost of technology development in the form of grants or experimentation. This is particularly true for powertrain improvements, electric vehicles, lightweighting and autonomous vehicles.
- Customer education, together with possible incentives, notably in the case of active safety, where the benefits are high and customer willingness to pay is limited.

[6]The Boston Consulting Group. *Revolution in the driver's seat: the road to autonomous vehicles.* Detroit, MI: BCG Report (2015). Retrieved from https://www.bcgperspectives.com/content/articles/automotive-consumer-insight-revolution-drivers-seat-road-autonomous-vehicles/

- Sustained incentives will be required to continue the development of electric vehicles, be it battery powered or fuel cells. These incentives might follow a number of different directions:
  - Evolve toward incentives based on industry wide volumes, as opposed to OEM specific volumes, in order to continue supporting the efforts of early innovators
  - Support of charging, or hydrogen distribution infrastructure, broadly speaking or for select experimentation
  - Support non-financial incentives for electric vehicles with reserved parking spaces or access to priority lanes
  - Support customers in upgrading their home-charging to 220V, which will be required for the next generation of electric vehicles with extended ranges
  - Potentially offer more credit to OEMs for electric cars used in a car sharing environment, where they are likely to have higher utilization
- Overall, the legislation will have to think about the adequate balance between fuel efficiency and safety in consumer and government spending. And define the appropriate balance of investment in improving conventional powertrain technologies compared to supporting zero emission vehicles.

The CHAIRMAN. Thank you, Mr. Mosquet.

We appreciate the testimony from each of you. It is always interesting to hear where the exciting developments are.

Mr. Bainwol, I am going to start with you.

I mentioned in my opening statement that I am in that group of lawmakers that is really reluctant for us in the government to be picking winners and losers whether it is as it relates to type of automobile or energy sources. Mr. Mosquet just led me right into this in acknowledging that some of the incentives and supports that we currently have are going to, in his opinion, need to be around for a while longer.

In looking at the charts that you have provided us, it is clear that what has happened with the lower price of gasoline at the pump has influenced consumers' decisions as to whether or not they are going with electric or hybrid.

Can you speak to this issue of, again, where we try to pick a winner and loser in an emerging area from your members' perspective and preferences, how should the Federal Government handle, or should they at all, promoting fuel and efficiency-related innovation that, inadvertently or not, may push in a direction that perhaps does put us in a situation where we are picking winners and losers?

Mr. BAINWOL. So the short answer is our members prefer an approach that is technology neutral. And so that's the short answer.

The longer answer is more complicated. We identify with the goal of reducing carbon. We identify with the goal of reducing fuel dependency, so all those things are noble, societal objectives.

The complications come from the nature of the regulatory regime, and what we have is an approach in CAFE that NHTSA measures by MPG. EPA measures by greenhouse gas. And then there's an overlapping state program from California, the ZEBB program, which is executed in a bunch of other states representing about 30 percent of the market. The ZEBB program is effectively not technology neutral. It's either, basically, to comply to their electrification or fuel cell, in today's world mostly electrification.

We're complying with different regulatory regimes which creates friction and added costs, and we get caught in the middle between a mandate on consumption. It's not a mandate on production. It's a mandate on what consumers buy. In a low gas tax environment, low gas price environment, consumers are moving away from the stated social objectives of electrification and moving folks into smaller cars rather than trucks. So it's a challenge.

Technology neutral is ideal. We have to recognize that consumers are going to respond in a fashion that's rational for them, and they're not into optimizing policy. They're into maximizing their pocketbook.

The CHAIRMAN. I appreciate that.

Ms. Cullen had mentioned in her testimony that contained within this bipartisan energy bill that we have moved out of Committee and that we are going to have on the floor next week, that there are some R and D provisions in there that are good for the industry. I appreciate you pointing that out.

Mr. Bainwol, is there anything else in that energy bill that the auto makers are looking at and saying this is helpful for industry?

Mr. BAINWOL. Yes. Well, first of all, a bill that's a major bill that has bipartisan support is a wonderful gesture around the country. It's a great symbol of the Congress working.

The CHAIRMAN. We want it to be more than a symbol. We want it——

Mr. BAINWOL. Well——

The CHAIRMAN. We want to update some policy.

Mr. BAINWOL. So it's good from the standpoint of consumer confidence, and consumer confidence is vital to purchasing big cost items, like cars. But more specifically there are provisions in the bill that are helpful.

The critical minerals piece matters. I showed the chart that has increasing price of cars mostly flowing from compliance. To the extent we can rustle challenges down like the critical minerals, we're stabilizing supply and reducing costs. That allows people to buy new cars, and that's terrific. So that's very helpful.

The VIA component that Senator Stabenow brought to the table is also very helpful. And we love the focus on V to V because at the end of the day V to V, NHTSA, you're no longer at NHTSA, but NHTSA has estimated that V to V can address 80 percent of all non-impaired accidents. So the fuel implications of that and the safety implications are substantial. So the assistance there is very helpful.

The CHAIRMAN. I appreciate you bringing up the critical minerals bill. Mr. Mosquet, you mentioned that as well in the context of material availability and what that means for the industry recognizing that we do not want to go in the same direction with our critical minerals that we were headed when it came to vulnerability and relying on foreign sources for our oils. That is something I think we are all paying attention to.

The 10:30 vote has started. I am going to excuse myself from the Committee and Senator Cantwell will ask her questions, and I would just ask her to go back and forth here. I think you will see members popping in and out. Do not take that as a lack of interest, but I will be back to ask another round of questions.

With that, Senator Cantwell?

Senator CANTWELL. [presiding]: Okay, thank you.

Thank you, Madam Chair, and I am going to defer to my colleague from Michigan so she can——

Senator STABENOW. Thank you very much, Senator Cantwell.

Senator CANTWELL. Yes.

Senator STABENOW. And Madam Chair.

First, I have to say that I could spend hours talking about this, obviously, representing Michigan and so many of the technologies are being developed through our industries in Michigan and our great universities that are collaborating with the Department of Energy and the Federal labs and so on. So vehicle-to-vehicle technology, autonomous technology, all the safety things that you are talking about that are so critical, as well as addressing energy savings and emissions and what is happening on a range of things, certainly, around battery development, fuel cells, I mean, all of it.

I do want to say though, Mr. Bainwol, and I am sorry that the Chair left because I will be talking to her more about this, that one piece that did not get into the energy bill that were looking forward

to doing on the floor is the provision that Senator Cassidy and I put forward on the advanced technology vehicles program, to be able to expand the flexibility of that to larger vehicles which are so important and to auto suppliers.

We know right now that the latest Department of Energy advanced technology manufacturing loan actually went to Alcoa in Tennessee to be able to help them continue the very exciting opportunities around aluminum. We know the F–150, I sound like ads for automobiles whenever I am talking about all of this, but the F–150 has been able to take 700 pounds out of their truck by using aluminum instead of steel, so composites and all of this.

Mr. Bainwol, I wonder if you might just expand on what I know is in your written testimony as well about the importance of taking an existing program and just giving it a broader portfolio so that we can address what needs to be done around larger vehicles and trucks.

Mr. BAINWOL. Well we certainly are supportive of your effort to broaden the eligibility to trucks and suppliers, so we think that makes sense and we Are delighted to be supportive of it.

Senator STABENOW. Great.

Mr. Friedman, from your perspective as well, how do you see that helping us as are moving forward to tackle energy savings and so on?

Mr. FRIEDMAN. Well it's clear that heavier vehicles are an incredibly important area that we have to tackle when it comes to fuel efficiency.

I think our super truck program has shown that there's a lot of progress that can be had. That progress needs to be backed up with investments, especially when you consider that long haul trucks account for about four percent of registrations but around ten percent of oil use. So clearly having more resources, having more opportunities to invest in proving those technologies is an important part of a balanced portfolio.

Senator STABENOW. Thank you.

In listening to all of you and in watching, and in going to the North American Auto Show and having a chance to sit in a lot of these vehicles, it is very exciting to see what is happening.

One of the things that I keep coming back to and, even Mr. Bainwol, even in your chart looking at what consumers are choosing, and certainly gas prices work against, sort of, as we look at new technologies and so on, but when we look at this what I hear all the time from people is a concern about lack of infrastructure.

Now at the auto show we were seeing hybrids, electric vehicles with 120 watt and you can plug it into a regular plug. But when I look at things like hydrogen fuel cells that have huge potential that our Department of Defense is doing work, of course, in all of these areas, but it seems to me that we have got to be focused much more aggressively at making sure the gas station is actually a service station and that you have the options there and that it is consumer friendly.

So I wonder, Dr. Gearhart, if you would want to respond to that and then Ms. Cullen and anyone else that would want to respond to the question of how do we really get there where we get over the huge barrier of lack of choice at the service station?

Dr. GEARHART. So I agree, particularly with hydrogen. It's a tie by, I understand.

So I agree with you, particularly with hydrogen fuel cell vehicles, that the lack of infrastructure is the big problem. I think that that's one of the big roles that the Federal Government can play is to make sure that the technology for the infrastructure is as ready as the technology for the vehicles are. The auto companies have done a fantastic job.

If you get a chance to drive the Mirai and any of the new vehicles, they'll knock your socks off. They're really great, but drivers are going to want reliable fueling stations that are online every time they go there. And if they don't, we're going to have a false start.

So that's why at NREL we've built a research station specifically for the purpose of looking at the reliability of the hydrogen infrastructure to make sure that the components are ready to identify mistakes. We're working with H2USA which is a public/private partnership of people in the industries to try to identify what are the critical items for them to make sure that the hydrogen infrastructure can get ready.

Senator STABENOW. Thank you.

I know I am out of time but, Ms. Cullen, if you could just briefly respond to that?

Ms. CULLEN. Well quickly I would say that I agree completely on the hydrogen infrastructure. It is premised, the fuel cell vehicle is premised, on a gas station model of centralized, say once a week, fueling.

For plug-in vehicles it's more of a cell phone model, work, home and opportunistic charging. And so responding to the needs of the work, home and public are slightly different. I would say that we are working, the industry is working, with the Department of Energy and state and local partners to actually build out those infrastructures on all of those levels.

Senator STABENOW. Thank you.

Senator CANTWELL. Senator Gardner?

Senator GARDNER. Thank you very much to the Ranking Member, and thank you to the witnesses for your time today, particularly Dr. Gearhart, welcome.

Dr. Gearhart, welcome to the Senate Energy Committee.

I enjoyed driving for the first time a hydrogen fuel vehicle at the Golden headquarters of the National Renewable Energy Laboratory last year, so it was a great opportunity to see the work that you are doing there.

Also for the interest of members, Senator Gary Peters and I have created a smart transportation caucus. Our focus is going to be on vehicle-to-vehicle communication and the kind of work that you are doing and talking about today. So if anybody is interested in those efforts, I would love to see you in the caucus and talk to Senator Peters and I for that. We have a range of issues that we can talk about. It is kind of fun to hear what everybody is working on.

In Colorado, of course, if you have driven to the mountains from Denver to Vail or to Beaver Creek at any time in the last several years, you have probably spent a couple of hours in traffic jams. The odds are we are not going to be drilling or adding an addi-

tional tunnel to the Eisenhower/Johnson tunnels any time soon, so the solutions that we have to look for are being talked about on this panel, the vehicle-to-vehicle communications and alternative transportation methods and modes.

I just have a couple of questions I think that go beyond this Committee. I mean, because we have questions of spectrum. How our cars are going to communicate with each other? Do we have enough spectrum to make sure that cars can communicate with each other?

We have issues of moral authority that are going to have to be determined. When a car is going to make a decision if it is driving by itself to take the ditch, to hit wildlife, the baby crossing the road because there is another car coming. These are all questions that over time are going to have to be worked out for moral choices that a driverless or autonomous car is going to have to make to the kind of communications that an older vehicle makes.

It is interesting in agriculture, of course, that we have been using driverless tractors, self-guided, auto-steering tractors for over a decade now. You can retrofit a 30- or 40-year-old tractor with a self-steering mechanism, and we have seen it bring increases in productivity to agriculture. Now, of course, what it could mean to solve transportation, you know, clogging the arteries of our transportation system is using this to solve that problem.

I know it was recently announced that the National Renewable Energy Laboratory had entered into a MOU with the Department of Transportation in Colorado for research on the I–70 and I–25 corridor when it comes to vehicle-to-vehicle communication.

Dr. Gearhart, can you talk a little bit about the work you are doing there?

Dr. GEARHART. Yes.

CDOT has announced their, what they're calling, the Road X program which is to look at the potential for using these automated and connected technologies in really all aspects. And they joined with the National Renewable Energy Lab, in particular, to bring in the fuel economy and the emissions aspect of it.

So we're in discussions with them. We're looking at a number of possible projects where we can help CDOT by collecting data and providing analysis for the data for them and confirming that these technologies do make the difference that we really hope that they make. So we're very excited about it.

In particular, we haven't quite found the I–70 corridor project but I'm really looking forward to the day that we, the car, drives me up I–70 rather than me sitting there in traffic. It's a very, very exciting partnership.

Senator GARDNER. What has NREL's research shown when it comes to potential congestion relief with connected vehicles? Are you able to model that yet? Have we gotten that far?

Dr. GEARHART. Senator, we're working on modeling it. Right now what we've seen if we look at the energy impact there can be dominated by several effects. If the dominant effect of introducing these new technologies is to make the traffic flow much, much smoother, we will reduce the energy per mile driven significantly.

The problem is now if we make it so convenient will people drive more miles? And so that's the big research question that we're looking at now is, you know, what is the bounce back effect of having

removed the barriers? If no one no longer cares that they're sitting in their car or they just drive more miles and does that then drive the emissions up even though that there are fewer emissions per mile?

That's a tough-to crack. It's as much about how consumers think and make decisions based on the information that they're receiving as it is on the technology, so I can't give you an answer right now. It could be anywhere from half of the energy consumed to twice as much energy consumed. But it's going to be a big effect, and I think we need to understand that what it is going to be as soon as possible.

Senator GARDNER. Well I think it would be a perfect solution to the victory the Broncos will have over Senator Warren's team, the New England Patriots, later this weekend. [Laughter.]

Senator GARDNER. So thank you very much for the opportunity to be here with all of you today.

Senator CANTWELL. Uh oh.

Senator WARREN. Dream on, Senator Gardner. [Laughter.]

Senator WARREN. Dream on. Your dreams will last a few more days.

Senator CANTWELL. The throw down. Who expected that?

Okay, Senator Warren?

Senator WARREN. Thank you, Madam Chairman.

You know, there are two ways to repeal a rule. You can repeal it outright to strike it from the books or you can paper over the rule with enough exceptions and alternatives that the rule becomes fairly meaningless.

Now the auto industry complains about ambitious fuel economy standards because it costs money to make cars more efficient and to reduce their pollution. The industry knows it can't win a head on fight to roll back fuel standards so it looks like the industry is trying the paper over it approach.

Here is how it works. Recently House Republicans introduced a bill to improve auto safety that includes a loophole to let the auto makers break from fuel economy standards. The bill lists nine specific safety technologies. It sounds good. Car companies have already agreed to install several of them, so this is obviously not a big stretch. But the bill says that if any auto maker installs three technologies from the list, they will be eligible for a credit equal to at least three grams of carbon dioxide per mile toward their greenhouse gas emissions requirements. In other words, this gift to the auto industry says you do what you have already agreed to do and you can slide by with lower EPA standards. It sounds like a pretty slick operation. Now what I cannot figure out is the calculation that three safety features should be worth exactly three grams of carbon dioxide per mile, not one gram or ten grams.

Mr. Bainwol, you represent the auto industry, and you have been a vocal supporter of this provision. Can you tell me whether your industry suggested this number to the House of Representatives or did the House Republicans give you the number?

Mr. BAINWOL. I think some context, if I could.

Senator WARREN. I just want to know who came up with the number.

Mr. BAINWOL. We did not originate the number. But let me——

Senator WARREN. So the House Republicans gave you the number and put three grams on any of those safety features?

Mr. BAINWOL. This was a draft provision that was shown to us. We did not ask for the grams per mile that were provided. But I mean you can contextualize it.

Senator WARREN. So you would be okay if they did not do it?

Mr. BAINWOL. Right. If I could contextualize it. The Tesla gets about 600 grams of credit. That's a car that cost roughly $135,000 to buy, and we're providing 600 grams of credit.

These safety technologies which, as we've discussed today, have a value for the environment, have a value for congestion, have a value for safety, have a value for fuel efficiency.

Senator WARREN. So Mr. Bainwol, let me——

Mr. BAINWOL.—Are 15, 140.

Senator WARREN. Stop you there. The question is not whether or not reducing congestion may or may not reduce pollution ultimately. I think this is actually a quite debatable point. There has been a lot of evidence on both sides of this that, as I understand it, economist Joe Cartwright puts it when it comes to pollution the evidence there suggests that if you reduce congestion people actually drive further and that more than offsets the effects of idling. I think this was related to the point that Dr. Gearhart was just making.

But that is not my question. I had just one question, and that is who calculated the number that it was three grams? If you are telling me the auto industry did not do it, then I just want to know who did it. You are out here lobbying for it. You say it is supported by scientific evidence. Where did the number come from?

Mr. BAINWOL. This was a draft document. I don't know where the number came from but it was an extraordinarily modest number in the context of what's regarded to Tesla and in the context of the overall CAFE target.

Listen——

Senator WARREN. Well, I appreciate that you think it is a small number but, you know——

Mr. BAINWOL. Well it's one theory as to what Tesla was recorded.

Senator WARREN. But we are not talking about Teslas. What we are talking about are gasoline powered engines here.

Mr. BAINWOL. So——

Senator WARREN. And we are talking about not meeting established EPA standards.

But I think that what is clear, and I asked you whether you have got any evidence on this and you said, no, even though you are supporting this and saying it is backed up by evidence.

Neither the idea nor the number is based on any concrete research. I think this is just trying to roll back part of the EPA rules without having to tell the American people about it.

In 2014 more than 32,000 people were killed in motor vehicle crashes, as you rightly pointed out. That is 32,000 reasons right there to encourage the adoption of promising safety technologies like automatic emergency braking.

Car companies should make cars safer and they should also meet their fuel economy obligations, period. If they do not want to do that then they should face the American people and explain how

they want softer pollution standards and then let's see what the American people have to say.

Mr. BAINWOL. But we——

Senator WARREN. Thank you, Madam Chair.

Mr. BAINWOL. May I respond, Senator?

Chairman Murkowski, may I have an opportunity to respond a bit?

So we signed up for the CAFÉ program. And as I noted, the CAFÉ program is a consumption mandate not a production mandate. I showed you the number of models, both electric hybrid, and high MPG models that we've generated and put in the showroom. So we are doing our part.

If it were a production mandate the issue would be over, but it's not a production mandate. It's a mandate on what consumers buy, and consumers are not buying the products that you want them to buy.

Senator WARREN. But——

Mr. BAINWOL. There's a challenge.

Senator WARREN. I asked for the scientific evidence for how it is that we have a build this proposed to say a few——

Mr. BAINWOL. But let's talk scientific evidence.

Senator WARREN. You do what you are already doing.

Mr. BAINWOL. Let's——

Senator WARREN. You are going to get credit, and so far all you have said is you are not the one who hasn't.

Thank you.

Mr. BAINWOL. Let's talk scientific evidence for just a second.

The CHAIRMAN. [presiding]: We are out of time, and Senator Warren does have to vote.

Mr. BAINWOL. Okay.

The CHAIRMAN. So maybe you can do that in response to another member.

Mr. BAINWOL. Perfect, thank you.

The CHAIRMAN. Thank you, Mr. Bainwol.

Senator Daines?

Senator DAINES. Chair Murkowski, Ranking Member Cantwell, thank you for holding this hearing on this very important and timely topic.

My home state of Montana is a big state. It is the fourth largest state. It is not as big as Alaska, Madam Chair, but we are the fourth largest.

We have a very dispersed population, over 75,000 miles of roads. We have the second highest rate of car ownership in the country, so it brings about unique challenges and extraordinary dependence on our transportation infrastructure.

Montana's extensive transportation system is a pillar of our economy. It allows visitors, residents and freight to traverse the state. It goes without saying, it is imperative that we keep people and freight moving as efficiently and safely as possible.

Today we have touched on the role of regulations and standards in driving auto industry innovation. My concern with mandates in this domain, like so many others, is that they typically do more harm than they do good. Based on cases we have seen under this Administration, they are often unattainable. They pinch the wal-

lets of hardworking Americans, hardworking Montanans, and they waste hard earned taxpayer dollars.

For example, as Mr. Bainwol points out, of the 17 and a half million vehicles sold last year only approximately 400,000 of them were plug in hybrids and battery electric and fuel cell vehicles, not even reaching half of President Obama's goal to have a million on U.S. roads by 2015.

Another case in point, in 2008 Congress mandated the installation of passive train control on freight rail tracks that carry passengers of certain hazardous materials by the end of 2015 despite the rail's best efforts. The complexity and sheer scale of this implementation make full development and deployment of PTC by the end of this year impossible.

Additionally, President Obama's Fiscal Year 2017 budget will request $4 billion for the development of autonomous vehicles. Meanwhile automakers are going to invest $800 billion a year globally on R and D to produce reliable and safe mobility solutions. Ninetynine percent of this investment in America is from private, nongovernmental sources according to the Alliance of Automobile Manufacturers.

We should continue innovating technology to make our vehicles safer and make them more efficient, but we should let consumers determine the market for vehicles not a bunch of Washington bureaucrats.

My question is for Mr. Bainwol. As you note, public policies and regulations do not always align with the preferences of consumers. Could you expand upon your vision for a more productive relationship and emphasize a productive relationship between industry and government, and how do you see reducing the Federal role in vehicle technology innovation may actually benefit the industry and benefit the consumer?

Mr. BAINWOL. That's a tough one, but easier than Senator Warren's question, so thank you.

The goal of fuel efficiency and electrification, those were social goals. And to get there requires an investment on the part of OEMs and that's the $100 million that you've referenced. It requires consumers playing ball because it is a consumption mandate not a production mandate, and it requires government being supportive either in the form of research help but again where it's 99 percent private or in the form of infrastructure to induce the purchase of electric and hydrogen vehicles. So it's a complicated matrix.

But once we've established that we're shooting for a target, we've got to find a way to get there. In a low gas priced environment that's a challenge, and it's exacerbated by the success of the conventional engine.

So we're kind of caught. We're engaged in the research. We're producing magnificent product. We want these programs to succeed, electrification, fuel cell and other alternative power trains, because we have to both because it's good for the environment but also because we have mandates to make that happen. But it's a trick because consumers do want to do what consumers want to do. They are rational in their behavior. And as I indicated earlier, policymakers seek to optimize that outcome and consumers are motivated by a different standard which is enough is enough.

If they can save $5,000 and apply that to a college education or to food on the table and not buy a hybrid, they may choose to do that. And then we're caught in the middle. It's a challenge.

Senator DAINES. It may seem counterintuitive to some, but how do you see reducing the Federal role in vehicle technology and innovation actually benefiting the industry and benefiting the consumer?

Mr. BAINWOL. So I think where government could be most helpful would be to get rid of regulatory friction. We have the ZEBB mandate for a quarter of the marketplace. It's not a Federal rule, but it's a rule that effects 25 to 30 percent of the country.

We have the NHTSA MPG requirement and we have the EPA greenhouse gas requirement, and they're not harmonized. If we had one national program, in truth, then it would be much more efficient to comply. We could reduce the cost of the vehicles. That would speed up adoption. That'd be a great thing.

So there's a way to square this, but we've got to get rid of regulatory burdens. We've got to provide the infrastructure support, and then there's a chance for it to succeed.

Senator DAINES. Thank you, Mr. Bainwol.

The CHAIRMAN. Senator King?

Senator KING. Thank you, Madam Chair. Sorry to be late. I was at an Armed Services hearing.

First I should say I am excited that I just bought an electric car and am looking forward to using it.

I apologize if I am repeating because I have not heard your testimony, but one of the most interesting aspects of electric vehicles, it seems to me, is the potential for a more efficient utilization of the grid because of the fact that most people will charge their cars at night which is the time when we have excess, both excess capacity and excess capability on the wires.

Is that something that you have discussed and if you have not, do you, anyone of you, wish to address it? Yes, sir?

Mr. FRIEDMAN. Thank you, Senator.

Let me say a few words about that because at the Department of Energy we just recently released the core of our plan for a grid modernization effort. And as part of that effort there's going to be over 220 projects looking at improving the reliability, resiliency of the grid and increasing its ability to integrate variable sources of energy such as wind power and solar power.

A couple of key parts of that are studying the ability to integrate electric vehicles, fuel cell vehicles, into the grid so that at night when you have more wind blowing you can use cost effective wind power. During the day when demand is up, maybe the batteries or fuel cell vehicles can provide electricity to the grid to help balance those loads.

I think that's a great example of why government has such a critical role in bringing these technologies to the marketplace and giving consumers more choices.

If you look back over my lifetime we've seen six major oil price spikes that have either dramatically slowed or reversed economic growth in the United States. And so we have to look at the long term as we invest in electric vehicles and in more fuel efficient ve-

hicles because if all we do is look at the gas prices today, just like in 2007, we're going to drive the auto industry into a ditch.

Instead we need to focus on investing on technologies that double fuel economy, that provide electrification and improve the resiliency of the grid to save people thousands of dollars, to tap into cleaner, lower carbon fuel sources and to give consumers a lot more choice in the marketplace.

Gas prices are going to spike again, and we've got to be ready.

Senator KING. Yes, ma'am?

Ms. CULLEN. Senator, in addition to the benefits of the mobile load that David mentioned, the rise of electrification is also building out the battery segment. It's scaling up options in both residential and utility and distributed energy storage. Both new and post automotive use batteries are being used too, as a grid resource.

Senator KING. Like the Tesla house battery that came out of the automobile technology

Ms. CULLEN. Correct.

The Tesla's partnership with Panasonic on their giga factory which is building markets for energy storage while building out, building scale in the battery segment.

Senator KING. But what I think a lot of people do not realize is that the grid is like a church built for Christmas day. It has enough room for all the parishioners, but on a slow Sunday in March there are a lot of empty seats. The wires are built for the heaviest day of the year and at night, particularly in the winter because they are more conductive in cold weather, at least in my region of the country, there is a tremendous excess capacity.

You could increase the load dramatically at night which presumably electric vehicles would without a dime of additional infrastructure investment. I think that is one of the attractive features of electric cars beyond just the fact of freeing yourself from dependence on the volatile fossil fuel price.

Ms. CULLEN. In fact one of the earliest studies of this from one of the labs estimated that if 73 percent of the vehicle fleet were electrified you could fill its need with existing grid capacity without adding any new generation.

Senator KING. Yes, I think that is an important point in this discussion other than the vehicles themselves.

I missed your testimony. In just the few seconds left are there new technologies on the horizon? The big issue is range, I suppose. And where are we on battery technology and getting to the place where we are going to have a 200- and 300-mile range on a change?

I remember a fellow who was going to have batteries that were removable so you could drive into the station and take out the old one. It is like trading in your propane tank. What happened to that idea?

Mr. FRIEDMAN. Well a couple of words on that.

First, I'm holding here a lithium ion cell that uses nickel manganese/cobalt technology that was developed at our national labs. This kind of technology is now being licensed to the auto industry. It's helping to drive electric vehicles like the Chevy Bolt to 200 miles range.

We're continuing to invest. And in fact, under mission innovation we need to look at dramatically increasing our investments in technologies like these so that consumers can have those 200-, 300-, 400-mile battery electric and fuel cell electric vehicles to give the exact benefits you're talking about.

Senator KING. Developments in battery technology have huge implications for rooftop solar, for example and also again, for grid stability. I think there is a national security interest here in decentralizing the grid so that it is not subject to a catastrophic centralized attack and could be more self-healing if you have distributed generation and distributed storage.

You are nodding. Can somebody say yes?

Ms. CULLEN. Yes.

Mr. FRIEDMAN. Yes.

Senator KING. Yes, nodding does not go.

Mr. FRIEDMAN. Yes, it doesn't.

The CHAIRMAN. For the record.

Senator KING. Yes, exactly.

Mr. MOSQUET. The one thing I would add is I think as we go to extended range batteries for 200 miles or more, which is actually the trend, I think we will probably need more 220 volts installation. And so there will be actually a need for some upgrade of the last mile of the grid, potentially also some support to the consumer who today is paying the bill of that increased span. And it was at some point, some support at this and local states for that and that's probably something we'll have to think about if we want people to access more with new cars like the Chevrolet Bolt which is offering much more mileage.

Senator KING. Madam Chair, may I ask one followup question? Oh, I am sorry. Senator?

Senator FRANKEN. I object.

Senator KING. Yes.

Senator FRANKEN. No, go ahead.

Senator KING. You are objectionable anyway, sorry.

Senator FRANKEN. Now I do object. [Laughter.]

Senator KING. Are there any estimates of the number of, or I guess you told me 70. We could go to 73 percent of the vehicles without changing the grid. Do we have estimates of what would be required to go to 220, for example? Does that require something new to the house or isn't 220 what a clothes dryer uses? So the house is just a matter of rewiring your house to have a 220 in the carport.

Ms. CULLEN. So just quickly. So a level one charging it's your standard.

Senator KING. Right.

Ms. CULLEN. Standard 120 outlet. Level two is 240 and that's what your dryer plugs into.

Senator KING. Right.

Ms. CULLEN. And that will charge your car.

Senator KING. And then there are the super chargers that will charge it——

Ms. CULLEN. DC fast charge and that's 480 volts, and that's more of a commercial and public installation not something you'd likely have in your garage.

Senator KING. How many people could have electric cars with short ranges? In other words, how many people only use their cars for short trips? Do we have data on that?

Ms. CULLEN. We do. In fact, the vast majority, more than 80 percent, of commuters travel less than 40 miles a day. And I think the charging patterns have shown that the fact is 80 percent of charging happens at work and at home, and the last 20 percent is public charging and opportunistic charging.

And not that that's unimportant because that's the part that adds to long distance travel, increases electric miles traveled overall. But in fact, the existing infrastructure is supported by workplace and home charging.

And the cost of installing T40 level charging, although they vary based on how old your house is, whether you have to upgrade the panel, in fact have come down materially.

Mr. FRIEDMAN. I think that's a really important point. I mean, we have a program called the workplace charging challenge which is focused on getting more and more companies, more and more partners, to install workplace charging even at the level one, 120-volt range. We're up to about 250 partners. We're looking to work toward doubling that.

And you know, I own a plug in vehicle. If I could plug in at work that could easily effectively double the range that I could use on a battery, so it's an incredibly effective option.

Senator KING. There are charging stations in the Senate garage. They charge an arm and a leg besides the car, but other than that, we do have them.

Thank you, Madam Chair.

The CHAIRMAN. Senator Franken?

Senator FRANKEN. I noticed that no one answered Senator King's question on the what happened to the battery that you pop in and pop out, and I was very intrigued by that because Israel was doing that.

The answer that I got, and I do not mean to do your job, but I think it was that Israel is a very small country, so electric cars make more sense and also they do not have many brands of car. The idea that the battery would be like a high percentage of Israelis would have the same car with the same battery. So I love the idea of it, but it does not seem to work for the United States.

Is that kind of accurate?

Ms. CULLEN. That is accurate.

There are the additional challenges that the business model not only requires a standardized vehicle and battery configuration that it can be swapped out, it also contemplates that you would have an inventory of very expensive batteries waiting for people to come in and get them swapped out.

Senator FRANKEN. Which makes sense if everybody has sort of the same car. What I loved about this was that I could ask questions about if it had a sound effect in it. So that is too bad.

Mr. MOSQUET. But so most countries, no longer the U.S., have abandoned the project and notably because of the logistic challenge of basically rebalancing the loads of batteries that may not be in the right places and would be shipping batteries from one station

to the other to rebalance the load. And so it seems not to be, actually, a great solution.

But fast charging actually at service stations is a solution that within 15, 20 minutes you could get, I don't know, 50 to 90 miles extra for your car. And then you'll do the last part of your travel. That's probably the solution that will be the most effective.

Dr. GEARHART. And that's the analysis I'd seen as well is that the opportunity cost of having that much space tied up in racks of batteries that the owners of service stations have much higher value uses for those spaces, so.

Senator FRANKEN. Glad that in addition to giving Senator King three extra minutes, I have spent my two minutes and 15 seconds on answering his question.

The CHAIRMAN. You are just here to help.

Senator FRANKEN. Yes, so I am just here to serve my other colleagues. That is why I'm so popular.

I was fascinated with all the testimony, and Mr. Friedman, your testimony laying out all the incredible advances that we are making.

When cleaner, reducing the cost of high energy, high power batteries by more than 45 percent in three years. This is very, very exciting, I think.

The one thing we had a few years ago, I know the Chairman remembers when we had members of the American Energy Innovation Council. Remember it was Norman Augustine of Lockheed and there was a guy from Cisco and General Jones, I believe. They were basically saying that we used to spend a higher percentage of our GDP on energy research.

At a time where, in the paper today 2015 was the hottest year on record by a significant margin over the previous hottest year which I think was, well I know was, the previous year, and we have a real problem here.

My question is, and it can be to anyone but especially Mr. Friedman, shouldn't we be spending more on basic research on this exact kind of research as a percentage of our GDP?

Mr. FRIEDMAN. Well in short the answer is yes, absolutely. In fact that's why President Obama joined with 19 other world leaders in November in kicking off an effort called Mission Innovation which is about trying to get, not only the United States, but the globe to potentially as much as double spending on clean energy research and development, and putting that investment toward technologies that can be investable by industry.

The way government works really well is by working on the tough problems that industry cannot do on its own and then being in a position to hand off those advances to industry, who can then provide more choices, more technologies, more options for consumers so that we can ultimately develop the low carbon diet we need to address global warming pollution.

Senator FRANKEN. We have done this successfully time and time again, including in the oil and gas industry with hydraulic or making possible this revolution that we have had in getting gas and oil out of shale. That was a partnership in many ways and it came out of our national laboratories.

To me, I just think it is absolutely essential that we spend more in healthcare and in the National Institutes of Health needs more funding for things like Alzheimer's, but this is so important and the benefits, the off shoots. Can you give me some data on what the benefits are of the money that we spend?

Mr. FRIEDMAN. Well a few examples and you know, you talked about public health. In many ways these are public health issues. The investments we've made to improve heavy duty diesel engines between saving fuel and saving lives by reducing asthma and lung disease, have delivered a 70 to 1 benefit to cost ratio as a result of Department of Energy investments.

Overall, if you look over the last 20 or 30 years, we've delivered a 24 to 1 benefit to cost ratio. So it's clear that when we invest in innovations, when we develop technologies that can save lives, save fuel, cut carbon emissions and cut oil use, we deliver back to taxpayers. I would argue we're a very good investment when it comes to the future of the nation.

And, you know, you talk about health care and pharmaceuticals, they spend about 50 times what we do on a sales basis on research and development than we do on clean energy. We need to close that gap.

Senator FRANKEN. Okay, well, thank you.

I know the Chairwoman at the beginning of this hearing was talking about being technology neutral, and I have heard this analogy to a race and that you do not know which horse is going to win the race. Having every horse on the track at the beginning is good and we do not know if hydrogen now is behind by some analogies in this race, but you never know at the end what is going to be the technology that wins the race. So I agree with the Chair.

The CHAIRMAN. Thank you.

I want to talk about what Alaskans are talking about right now, trucks, because we drive a lot of trucks. I was prompted on this by Senator Daines as he mentioned, Montana is big. You have a lot of open spaces. Alaska is big, and we have a lot of open spaces. We haul a lot of gear. We just haul a lot of things whether it is the boats or the four wheelers or the snow machines or the stuff that you just move around. We haul it in worse conditions than Washington, DC is seeing here. We have actually got real snow accumulation. There is a lot of interest in terms of where the industry is going, when it comes to these technologies.

I noted in my opening statement that Ford is looking at an F–150 that can run on compressed natural gas and propane. Certainly that is interesting, but when we talk about the difference we are making with lighter vehicles to gain fuel efficiencies, that is important. You cannot have it too light or then you have your trucks sliding all over the place and you cannot haul what you need to haul.

Tell me where we are in meeting that consumer demand, because in certain parts of the country I would venture to say that there are probably a lot of people here on the Eastern seaboard that are really interested in what is going on with how we are making our trucks more fuel efficient, but still safer and still very, very capable.

In addition to that, recognizing that in places like Alaska or Minnesota, you have some very cold temperatures, so some of the things that we're talking about with our fuels——

Senator KING. Or Maine.

The CHAIRMAN. Oh, my gosh. I am looking at you at the other end of the table here, of course, Maine.

Senator KING. When you go to Northern Maine all you see are trucks.

The CHAIRMAN. My Arctic Caucus co-chair here. [Laughter.]

The CHAIRMAN. But these are some of the issues we face when we are dealing with colder temperatures and trying to meet the fuel standards and requirements, again, with trucks. Where are we with trucks? Somebody talk to me. You all need to talk to me about trucks because that is what Alaskans are talking to me about when it comes to their vehicles.

Mr. BAINWOL. So I'll start by making I guess, two points. The first is that at the end of the day, as I mentioned, this is a consumption mandate.

The CHAIRMAN. Right.

Mr. BAINWOL. And we have to respect what consumers want to do. The CAFÉ program tries to do that by establishing a program that's footprint-based.

The CHAIRMAN. What?

Mr. BAINWOL. Footprint-based.

The CHAIRMAN. Okay.

Mr. BAINWOL. So the 54–5 is a composite that is, kind of, a weighted average of what cars get, of what larger cars get, what trucks get. And so it's all blended. And so it does provide for some flexibility for trucks.

Now moving forward in the out years the cliff or the rated growth in terms of expectations on fuel efficiency for trucks is rising. And so it is a trick, but it's not the same number as the 54–5.

And so, our mission as auto makers is both to strive to comply with the obligations of CAFÉ but also to provide what consumers want. I think at this point that part is, in the early years, working.

The CHAIRMAN. Some others.

Where are we on the technologies in advancements?

Ms. Cullen?

Ms. CULLEN. Senator, the choices in electrification are also making their way into those heavier segments of vehicles. If you get to the auto show you will see hybrid, plug-in hybrid, and fuel cell SUVs and crossover vehicles. The auto makers are meeting the demands of their consumers for drivetrain capability as well as their drive cycles.

There are also great advances being made in the next segment up, for instance in medium duty. For instance, there are plug-in hybrid trouble trucks so that when a utility goes out late at night it can work on a site silently using its electric power to operate the, activate the bucket. Thus they operate cleanly, quietly and safely because the workers on the ground can hear what the arm is doing.

Moving up through the weight scale then the heavy duty segment. There are fuel cell buses on the road today. They accommo-

date those heavier loads, and based on their range and performance they're optimized for that application.

The CHAIRMAN. But we are still not seeing them in the trucks. You know, we are a three truck family and we are still looking at the older trucks that are out there.

Mr. FRIEDMAN. Well and the story with trucks.

The CHAIRMAN. Mr. Friedman?

Mr. FRIEDMAN. In many ways it is actually, right now, it's a story about innovations that are dramatically boosting the efficiency of internal combustion engines.

I mean, you can buy a truck engine now that's a V6 instead of V8. It gives you all the haul and power of that V8. It cuts weight. It delivers the same or better safety performance, and a lot of those technologies were supported by investments from the U.S. Government.

So I would argue there's been massive progress when it comes to pickup trucks and SUVs. It's just not as obvious in some ways because it's under the hood or it's in the materials. But when you look at the standards that Mitch was talking about you can roughly think of it is no matter the size of your vehicle you're going to roughly double the fuel efficiency of that vehicle.

For a truck, that's even more valuable than for a car because you use so much more fuel. So you can save money on fuel, have the same hauling power, the same or even better safety with technologies that Ford and GM and others have been, I think, helping lead the way on.

Nissan right now is about to introduce a Cummings Diesel into their Titan pickup truck. It's dramatically boosting fuel efficiency using a diesel engine. So real, great progress on the internal combustion engine and weight reduction side for those big vehicles.

The CHAIRMAN. Dr. Gearhart, are we doing anything at NREL?

Dr. GEARHART. Yes.

Another thing I'd like to add to this is at NREL, for example, we're looking at the various molecules that we can get out of biomass and the unique fuel properties that are associated with those different molecules that when combined in different ways and combined with what we can get from petroleum feed stock, that's going to enable, I think, the next generation of combustion improvements. And so, we'll be able to continue to make improvements on the efficiency of internal combustion engines while increasing the renewable feed stock that's going into those liquid fuels. I think those two together have a potential to give us fuel economy and reduce greenhouse gas emissions.

I think there's a lot of room that hasn't been pursued there. If we start to look, not just at engine efficiency but also what we can do on the fuel side, to use various bio feed stocks.

The CHAIRMAN. Good.

Senator King, if you want to do wrap up questions, please do, and then we are going to let our panel go at 11:30, as promised.

Senator KING. Thank you, Madam Chair.

First, I want to thank you for holding this hearing. I think this is an important topic, and I appreciate your allowing us to have this discussion.

Mr. Mosquet, I am interested in the money in the finances of this. When will electric vehicles be fully competitive and not need a tax credit and particularly with regard to gas prices? I heard recently about one state whose tax credit went away and the sales plunged.

The real question for any renewable, it seems to me, is when can it stand on its own two feet. I would like your thoughts about where this goes. Of course, I realize there is a lot of speculation about what are gas prices. It is hard for anything to be competitive with gas at the price it is today. But your thoughts?

Mr. MOSQUET. So, as you said, Senator, there's nothing sure about the future. But I think it may take some time. That would be the short answer for a number of reasons.

First, if we look today at the evolution of the cost of the technologies, I mean, they have significantly reduced that cost. But if we want to have cars that have a 200 miles or plus driving range, we will need 50, 60 kilowatt hours of battery to fuel those cars. Then the cost even when the sales are at $100 per kilowatt hour, multiplied by 50 you see what the cost is going to be to the OEMs. So it will remain a significant cost. But it depends then on what are the breakthroughs that are going to come up to take that. I would say another 50 percent down. It's not impossible, but it's probably a few years out. It's also highly dependent on the price of, you know, gasoline, of course.

We did our initial calculations with ranges of anywhere between $120 and $180 per barrel and we're not there today because consumers are looking for paybacks up to typically three years to buy more fuel efficient vehicles. We're far from this for years.

Senator KING. Well the current plunge in oil prices is attributable directly to my having made the decision to buy the electric car because it just——[Laughter.]

Mr. MOSQUET. But that's the good thing is I think. The more we improve the efficiency of conventional engines and the more we develop battery technologies and fuel cells, the more we keep the oil prices down. And so I think it's both actually a winning proposition for the consumer and for the country but at the same time it makes the life of the battery electric vehicle tougher in the long term.

Senator KING. It is interesting you should say that. An old professor friend of mine, Richard Hill, an engineering professor at the University of Maine, made the most profound observation about oil prices I have ever heard.

He said,"Oil prices in the future will always be the opposite of what you expect. If you expect them to be high and act accordingly by conserving and doing more conservation kind of measures, then that will create an excess supply which means prices will be low. If you think they're going to be low and you buy cars that get eight miles per gallon, then they're going to have a contraction of supply and prices will be high."

I have always thought that was an interesting observation. Oil prices in the future will always be the opposite of what you expect.

Mr. MOSQUET. Which means, by the way, that I think maybe it's not the market that we have to let evolve naturally. I think that this is why the legislation is important because otherwise you get the opposite effect of what you think you're going to get.

Senator KING. Madam Chair.

The CHAIRMAN. Thank you, Senator King.

Thank you to each of you for the contributions that you have provided to the Committee here this morning. I think it has been useful. It is always nice to know what is new.

I guess if we really want to see it, touch it, and feel it, we should go to the auto show and see the advancements that have been made. But I think it is clear that we are moving forward in different spaces. Quite honestly, the driverless cars are one that it is going to take me a while to get comfortable with.

But the advances we are making in ensuring that there is a level of safety, that there is a level of efficiency, all while responding to what the consumers are hoping for in a range that is affordable is good news for us.

So with that, I thank you for your contributions this morning, and we stand adjourned.

[Whereupon, at 11:28 a.m. the hearing was adjourned.]

APPENDIX MATERIAL SUBMITTED

Department of Energy
Washington, DC 20585

February 23, 2016

The Honorable Lisa Murkowski
Chairman
Committee on Energy and Natural Resources
United States Senate
Washington, DC 20510

Dear Madam Chairman:

On January 21, 2016, David Friedman, Principal Deputy Assistant Secretary for Energy Efficiency and Renewable Energy, testified regarding innovative technologies within the automotive industry.

Enclosed are answers to three questions that were submitted by Ranking Member Maria Cantwell for the hearing record.

If you need any additional information or further assistance, please contact me or Lillian Owen, Office of Congressional and Intergovernmental Affairs at (202) 586-5450.

Sincerely,

Jaime Shimek
Deputy Assistant Secretary for Senate Affairs
Congressional and Intergovernmental Affairs

Enclosures

cc: The Honorable Maria Cantwell
Ranking Member

QUESTIONS FROM RANKING MEMBER MARIA CANTWELL

Q1. My state of Washington has been a leader in the development of lightweight carbon fiber composites, now we want to be a leader in recycled carbon fiber. Current processes for manufacturing carbon fiber composites are very energy intensive and recycling carbon fiber into new composites uses half as much energy.

As the demand for carbon fiber increases, this will present new commercial opportunities for recycled carbon fiber.

Is the Department of Energy suited for the research and development of recycled carbon fiber?

A1. Yes, the Department is well-suited to address the research and development (R&D) challenges of recycled carbon fiber and other advanced composites and appreciates your interest in this area. The ability to reuse carbon fibers and the creation of a strong recycling and reuse market can have a significant positive impact on the life-cycle energy and greenhouse gas footprint for composites, as well as on the cost. As noted in the "Innovating Clean Energy Technologies in Advanced Manufacturing" section of the Department's 2015 Quadrennial Technology Review (QTR), innovation in recycling is a key technical priority for the development of composite materials for cost-effective and energy-efficient lightweight materials in future energy systems. Cost-effective recycling technologies for carbon fiber composites and collection supply chains need to be developed to save a significant amount of energy, particularly if the process enables repeated recycling without loss of technical quality.

To support the advancement of technologies towards these goals and support U.S. leadership in advanced composites for clean energy applications, the Department of Energy (DOE) through the Advanced Manufacturing Office (AMO) has recently launched the Institute for Advanced Composites Manufacturing Innovation (IACMI). This Institute will target the development of low-cost, energy efficient manufacturing and recycling of carbon fiber composites to support U.S. prosperity and security, further the mission of R&D in energy efficient and renewable technologies, and contribute to the National Network for Manufacturing Innovation (NNMI). Specifically, the IACMI public-private partnership will aim to develop technologies and capabilities with the potential to increase the ability to recycle carbon fiber composites by more than 95 percent within the next decade. The Department and IACMI are actively engaging with

stakeholders from industry, academia, and the research community who are interested in discussing potential partnerships with IACMI. Currently, the IACMI has nearly 100 members.

In addition, because cost is the most significant barrier to the technology adoption, the Department has supported development and validation of low-cost, carbon fiber materials through the use of cost-shared competitive R&D with industry, universities, and national laboratories. This includes support for validating the low-cost manufacturing of carbon fiber using innovative manufacturing processes and low-cost source materials.

Q2. With the success of the Super Truck program, where do you see the focus of the Second Phase of the Super Truck program? Do you see the Super Truck program focusing on other technologies such as connected devices or the Internet of Things that can provide real time data in areas like efficiency and fuel consumption?

A2. Building on the success of SuperTruck I, which will conclude in 2016, Energy Efficiency Renewable Energy's (EERE) Vehicle Technologies Office (VTO) will support new awards in FY 2016 for a SuperTruck II initiative to research, develop, and demonstrate a suite of technologies to improve the freight hauling efficiency of heavy-duty Class 8 long-haul vehicles by more than 100 percent by 2020 (with respect to comparable 2009 vehicles) with an emphasis on cost-competitiveness. Successful projects will also demonstrate applicability of these technologies to heavy-duty regional-haul vehicles; improving the efficiency of heavy-duty regional-haul vehicles is becoming more important as fleets shift to day cabs to accommodate shorter hauls.

To ensure high-impact and additionality, SuperTruck II applicants must propose a maximum freight hauling efficiency target greater than 100 percent and describe the approach and technologies they will use to meet that target. Project participants will be evaluated on their selection of advanced technologies for development that move beyond previous research, development, and demonstration efforts and attain breakthrough freight hauling efficiency improvement and technology cost-effectiveness. Participants will be required to maintain current levels of vehicle performance (acceleration and gradeability) while meeting prevailing federal emission and safety standards.

In addition, SuperTruck II places greater emphasis on technology suites that can be more cost-effective for end users to purchase and operate. The DOE's specific focus is on technologies (or systems of technologies) with realistic potential for cost-effectiveness as expressed in terms of a simple payback (years to recoup initial investment through fuel cost savings), with shorter payback periods being deemed more cost-effective than longer periods.

To reach these goals, SuperTruck II teams will pursue a number of advanced technologies and innovations to improve engine efficiency and emission control, advanced transmissions and hybridization, waste heat recovery, aerodynamic drag of the tractor and trailer, tire rolling resistance, lightweight materials, drivetrain efficiency (transmissions and axles) and auxiliary power units to reduce engine idling, and other technologies such as map-based powertrain and route management, and driver feedback/coaching devices.

SuperTruck I teams relied on multiple integrated technologies in order to meet the significant freight hauling efficiency goals of the program. Many of these technology solutions were made possible through advances in vehicle connectivity, information exchange, and computational capabilities. For example, teams incorporated features such as advanced route management, intelligent auxiliary systems control, look-ahead energy management, smart cruise-control, and predictive engine and hybrid-system controls based on real-time maps, terrain, and traffic data, which allow the vehicle to operate as efficiently as possible given external conditions.

In SuperTruck II, it is expected that connected and automated features may play an even greater role as teams develop solutions to reach the greater than 100 percent freight hauling efficiency improvement target. Technologies that automate certain aspects of truck control functions, including speed, braking, steering, throttle, and motive power under specific traffic or environmental conditions, may contribute to the overall freight efficiency of vehicles developed through SuperTruck II. As connected and automated technologies become more cost-effective, truck manufacturers and fleets will have the opportunity to incorporate these

features into their vehicles and realize information-based fuel and cost savings beyond those achievable through physical technology improvements alone.

Q3. With the potential for energy savings and reduced emissions in the transportation sector, how do you see Mission Innovation partnering with the transportation industry?

A3. Mission Innovation involves a plan to double clean energy R&D funding by 20 countries around the world. Within the U.S., this effort is focused on clean energy R&D across the Federal Government, and includes all of EERE's R&D programs, including the Bioenergy, Hydrogen and Fuel Cell, and Vehicle Technologies Offices that comprise our transportation portfolio. The proposed Mission Innovation investments in sustainable transportation technologies and other programs within EERE are available in the FY 2017 President's Budget. The FY 2017 President's Budget also includes a new 21st Century Clean Transportation program within EERE. Leveraging and building on EERE's core model, this proposed program will: 1) expand investment in transportation technologies of the future; 2) establish regional fueling infrastructure to support the deployment of low-carbon fuels; and 3) accelerate the Nation's transition to a cleaner vehicle fleet.

As part of its investment in transportation technologies of the future, DOE will scale-up clean transportation R&D through initiatives to accelerate cutting the cost of battery technology; advance the next generation of low carbon fuels such as biofuels, in particular for intermodal freight and fleets; and investigate system level energy implications of future mobility and intelligent transportation system technologies such as vehicle connectivity and automation.

The 21st Century Clean Transportation program seeks to ensure all Americans have access to at least one alternative fuel by 2020 by providing funding for the development of regional fueling infrastructure for low-carbon fuels including charging stations for electric vehicles, advanced biofuels, hydrogen fuel cells, and other low carbon options. This program is directly targeted at breaking the chicken or egg problem faced by alternative fuel vehicles for decades, where consumers were limited by infrastructure, and supply companies were limited by uncertainty in the market. Additionally, DOE plans to launch an Electric Vehicle Accelerators Communities program with the goal of deploying 10,000 new grid-connected

solar powered fast charge stations or renewable hydrogen refueling stations by 2025 through public-private partnerships.

In order to accelerate the transition to a clean vehicle fleet, DOE plans to also launch the Clean Fleets Competition program that will use challenge grants to support state, tribal, and local government vehicle fleets to purchase clean transportation options and operate them on low-carbon fuels, including those for first responders. As part of the Administration's intent to invest in a 21st Century Transportation System, investments are also proposed for other agencies with transportation research programs, including the Department of Transportation and NASA.

U.S. Senate Committee on Energy and Natural Resources
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Questions for the Record Submitted to Ms. Genevieve Cullen

Questions from Ranking Member Maria Cantwell

Question 1: As more electric vehicles enter into the marketplace and are on the road, this presents an opportunity for infrastructure development.

What are some of the obstacles in deployment of electric vehicle charging infrastructure?

The diversity of drivers and duty cycles means that charging infrastructure also needs to be diverse. Drivers need access to charging at home, at work, in commercial locations and on long trips. The kind of charging infrastructure (Level 1, Level 2 or DC fast charge) varies with the location and expected use.

Plug-in electric drive vehicles are overwhelmingly charged at home and work, where the vehicles are parked for long periods. Level 1 and Level 2 charging infrastructure deployment has been successful in meeting drivers' needs for charging at those locations. The challenges in general public deployment are often a function of the permitting and standards deviations at the state and local level. Greater standardization and streamlined permitting are helping to reduce these hurdles.

Access to charging at workplaces and public parking garages is expanding rapidly, aided by the federal tax incentive for charging infrastructure and increasing access to information resources, including the Department of Energy's Workplace Charging Challenge.

For the approximately 20 percent of charging that occurs outside homes and workplaces, the sites must be convenient, visible (if only on a locator app) and suit the time profile of users that frequent the locations. For instance, locations where a driver might be expected to remain for an extended period (e.g., a shopping mall or movie theater) could effectively deploy Level 2 charging for their customers.

For long distance travel or rapid charging, drivers want a DC fast charge option that can provide 80% of charge in 15 minutes. With DC fast charging facilities, there are increased installation and equipment costs compared to Level 2 charging.

On a larger scale, the need for a variety of charging options in a variety of locations means will call for a coordinated approach to infrastructure, with public and private stakeholders working together to ensure the most effective deployment strategies.

Support for private investment is critical. There are varying state level incentives for charging infrastructure. The Section 30 C federal tax incentive also helps to build the market and makes charging more accessible for consumers.

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Question 2: How can industry partner with the Department of Energy to bring about increased infrastructure? Would guaranteed loans or other financing tools help increase deployment of infrastructure?

For large scale – corridor and multi-state fast charge installations – federal support is important because the investment in some cases precedes the market, i.e. vehicle purchases increase as a result of the availability of charging options.

Automakers are working with charging and utility companies to build out infrastructure. A truly seamless, national scale infrastructure effort needs federal support in financing and planning. Providing financing support, such as loan guarantees, would increase access to capital for these innovative projects. Providing reinforcing resources in the form of competitively awarded grants or loan guarantees for projects along corridors designated under the Department of Transportation's newly authorized Alternative Fuel Corridor program would also enhance the impact of that program.

Consistent annual support for existing Department of Energy (DOE) programs that support infrastructure deployment is also important. Specifically, DOE's EV Everywhere program provides important technical assistance and support to infrastructure efforts and promotes collaboration among stakeholders. The Clean Cities program has a documented record of success in alternative fuel infrastructure and the program's success is only limited by the size of the resources appropriated on an annual basis.

Question 3: How can electric vehicles and distributed generation work together to provide more choices and benefits to consumers?

Electric vehicles are a form of distributed energy storage/generation. The battery can be used as energy storage when it is not powering the vehicle. As such, grid-connected vehicles are, in themselves, part of the growing number of distributed energy systems.

As a matter of market development, the expansion of electric dive is also helping to build energy storage opportunities. The growth of the lithium ion battery industry serving electric transportation is driving down the cost of batteries, which are being used in residential, commercial and utility scale applications to manage grid demand, store intermittent renewable power and increase the resiliency of the grid.

For example, the use of automotive batteries in solar charging stations (grid connected or dispersed generation) enable storage of excess solar power for use when needed. The batteries remove the intermittency challenges of renewable power, making it a more compelling distributed generation option.

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Batteries can also improve overall system reliability where distributed generation units are large enough to serve local loads in the event of a system outage.

Plug-in vehicles are also reinforcing the advance of distributed generation controls as charging demand management and vehicle to grid technologies and protocols are being integrated into modern grid operation.

U.S. Senate Committee on Energy and Natural Resources
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Questions for the Record Submitted to Dr. Chris Gearhart

Questions from Ranking Member Maria Cantwell

Question 1: What role do you believe our national labs can play into the research, as well as deployment of advanced materials like recycled carbon fiber?

The multi-agency National Network of Manufacturing Institutes (NNMI) is putting major emphasis on advanced materials. Last year a team led by NREL and Oak Ridge National Laboratory was selected to lead the Institute for Advanced Composites Manufacturing Innovation. This institute is dedicated to finding new ways to increase speed and production, reduce energy used, expand recycling, and improve a range of related technologies in the field of composites manufacturing. The Institute for Advanced Composites Manufacturing Innovation will include a Center of Excellence for using composites in the automotive industry, based in Michigan. (Colorado is named as a Center of Excellence for composite use in wind turbines).

NREL is also leading a consortium of other research institutions and industry on a program to cost-effectively produce carbon fiber material from non-food biomass. Additionally a wide range of promising advanced materials R&D is being undertaken at Oak Ridge National Laboratory, within the Department of Energy's Carbon Fiber Technology User Facility.

Question 2: How does light weighting of vehicles impact non-combustion engine vehicles like electric vehicles?

Light weighting reduces the amount of energy required to accelerate the vehicle and it reduces the energy lost due to friction between the tires and the road. These benefits are independent of the powertrain. The benefits of light weighting are greatest for start-stop driving because this is dominated by the energy required for acceleration. It has relatively less benefit for highway driving. Highway driving is generally high speed and relatively steady speed. The primary energy losses for longer range highway driving come from aerodynamic drag, which is not impacted by light weighting.

Given their advantages, the use of lightweight materials in vehicles has been increasing. About 30 percent of the material in today's vehicles is comprised of high-strength steel, aluminum, or composites. This has allowed for a reduction in the weight of the base structure of the vehicles. Much of this reduction in component weight has been used to improve comfort or performance, rather than simply reducing overall vehicle weight.

A 10 percent reduction in total vehicle weight can result in a 6-8 percent improvement in fuel economy. A 20-25 percent reduction in vehicle mass should be possible without significant redesign, or a reduction in safety or comfort standards.

The DOE's Vehicle Technologies Office and Advanced Manufacturing Office are working with the national labs through a number of partnerships to develop lightweight materials. These include the U.S. DRIVE Partnership's Materials Tech Team, the U.S. Automotive Materials Partnership (USAMP), and the Lightweight Innovations For Tomorrow NNMI. This work is being supported by the Materials Genome Initiative, an interagency initiative supporting the development of advanced materials. This work generally falls into four categories: development of computational tools to better understand new materials, improving the properties of materials, developing improved manufacturing methods, and developing new advanced materials and alloys.

American Chemistry Council
Statement for the Record
Senate Committee on Energy and Natural Resources

"Hearing to Examine the Status of Innovative Technologies Within the Automotive Industry"

January 21, 2016

The American Chemistry Council (ACC) appreciates the opportunity to comment on the Senate Committee on Energy and Natural Resources hearing entitled, "Examining the Status of Innovative Technologies Within the Automotive Industry." Representing over 180 companies engaged in the business of chemistry, ACC is an innovative $801 billion enterprise and a key element of the nation's economy. ACC members apply the science of chemistry to make innovative products and services that make people's lives better, healthier and safer.

The business of chemistry, including manufacturing of lightweight plastics and polymer composites used by the transportation industry, creates over 800,000 manufacturing and high-tech jobs, plus six million related jobs that support families and communities. The products of chemistry, such as plastics and polymer composites, make it possible to provide clean air and water, safe living conditions, efficient and affordable energy sources, lifesaving medical treatments and safe and innovative transportation solutions. Given the focus of today's important and timely hearing to consider the status of advanced technologies in the automotive industry and to prepare the federal government for the next generation of innovative vehicles, ACC would like to share background on our work in this important area.

Automotive technology is changing rapidly with the goal of creating more sustainable personal transportation and associated infrastructure. Manufacturers are increasingly utilizing innovative light-weight plastic and composite materials to increase auto fuel efficiency. This trend is likely to accelerate as automakers across the country take steps to meet the Corporate Average Fuel Economy (CAFE) standards. As vehicles become lighter in weight, Congress, the National Highway Traffic Safety Administration (NHTSA), automotive manufacturers and automotive material suppliers, including ACC members, play a critical role in ensuring that safety continues to improve.

Since FY 2006, Congress has devoted $1.3 million to the NHTSA to study the safety benefits of using plastics and composites to lightweight vehicles as a tool to achieve new CAFE

standards. ACC continues to be pleased that the products of chemistry – including lightweight plastic and polymer-based materials – have helped increase fuel efficiency, enabled more flexible vehicle designs, and helped improve auto safety, and that the NHTSA continues to facilitate these developments with necessary pre-competitive safety research and development, dynamic modeling and crash testing. In the Consolidated Appropriations Act, 2016 (P.L. 114-113) signed into law by President Obama on December 18, House and Senate committee report language relating to plastics and polymer composite materials became effective. Both House and Senate Transportation, Housing and Urban Development appropriations reports encourage NHTSA to advance "computer modeling of advanced plastic and polymer composites" while validating the safety of "polymer-based composites in structural applications for the automotive industry." Similarly, House and Senate Energy and Water appropriations reports both direct funds to "overcome the barriers to widespread adoption of lightweight material designs that include magnesium alloys, aluminum alloys, high-strength steels, and fiber-reinforced polymer composites."

Fully implementing the NHTSA Safety Roadmap will help ensure automakers have the tools they need to continue to make automobiles more fuel efficient and lightweight while maintaining vehicle safety.

NHTSA's continued work on the Safety Roadmap is needed to ensure that necessary pre-competitive research and development continues. This includes computer modeling for advanced plastic and polymer composites to help ensure accuracy in crash simulations. In addition, increased non-destructive testing and evaluation capabilities for plastic and polymer composites can help ensure safety integrity. We appreciate the Committee's support to continue this important, pre-competitive safety research at NHTSA to support the next generation of innovative vehicles.

Plastic and polymer composite products contribute robust and distinct economic benefits to our nation. Produced at 1,572 plants in 45 states, employing over 54,000 people and featuring a payroll of over $2.5 billion, advanced plastics and composites in the automotive sector have doubled in use over the last twenty years.

Plastics and polymer composites are helping to solve many of our nation's transportation challenges, including those faced by automakers seeking to achieve current and future federal safety standards for vehicles and light trucks. Technological innovation plays an important role. For example, carbon fiber reinforced plastic can absorb up to twelve times the crush strength of steel and has the potential to reduce the weight of some vehicle components by as much as seventy-five percent. As manufacturers continue to lightweight vehicles in order to meet increasingly challenging automotive requirements, NHTSA needs to ensure that data and standards exist to achieve light-weighting while maintaining vehicle safety.

Together, the plastics and polymer composites industry can successfully harness new and innovative vehicle technology to help auto manufacturers achieve safety requirements, fuel efficiency and contribute to reduced greenhouse gas emissions.

ACC applauds the Senate Energy and Natural Resources Committee for its efforts to advance innovative technologies in the automotive sector. ACC supports this work and highlights the increasingly important role of lightweight plastics and polymer composites in manufacturing innovative automotive technologies. We look forward to continuing to work with the Committee, Congress, NHTSA and all stakeholders on the development of emerging technologies and manufacturing processes to improve fuel economy and auto safety.

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http://www.americachemistry.com

The American Chemistry Council (ACC) represents the leading companies engaged in the business of chemistry. ACC members apply the science of chemistry to make innovative products and services that make people's lives better, healthier and safer. ACC is committed to improved environmental, health and safety performance through Responsible Care®, common sense advocacy designed to address major public policy issues, and health and environmental research and product testing. The business of chemistry is an $801 billion enterprise and a key element of the nation's economy. It is the nation's largest exporter, accounting for 14 percent of all U.S. exports. Chemistry companies are among the largest investors in research and development. Safety and security have always been primary concerns of ACC members, and they have intensified their efforts, working closely with government agencies to improve security and to defend against any threat to the nation's critical infrastructure.

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Statement for the Record
John Bozzella
President and CEO
Association of Global Automakers, Inc.

Before the Senate Energy and Natural Resources Committee Hearing to Examine the Status of Innovative Technologies within the Automotive Industry

January 21, 2016

Thank you Chairman Murkowski and Ranking Member Cantwell for holding a hearing to examine innovative technologies within the automotive industry. The Association of Global Automakers, Inc. (Global Automakers) represents international automobile manufacturers that design, build, and sell cars and light trucks in the United States. These companies have invested $52 billion in U. S. based facilities, directly employ more than 97,000 Americans, and sell 47 percent of all new vehicles purchased annually in the country. Combined, our members operate more than 275 production, design, R&D, sales, finance and other facilities across the United States. Global Automakers and our member companies are committed to creating the safest, cleanest and most technologically advanced vehicles on the road. While I understand some of my statement may be outside the jurisdiction of the Senate Committee on Energy and Natural Resources, there is no question that emerging vehicle technologies are reshaping how we power personal transportation and will have significant implications on the energy sector.

The auto industry is experiencing an extraordinary period of innovation, and our members are helping set the pace. Their efforts have resulted in improved vehicle fuel economy in traditional powertrains and the development of alternative fuel vehicles. Additionally, automated and connected vehicle technologies are changing the way we think of mobility and efficiency. As crash avoidance systems, vehicle-to-vehicle communications, improved traffic management plans and other advancements are integrated across the vehicle fleet, we will begin to see system wide benefits - our roads will be safer, our trips will be shorter, our air will be cleaner, and fewer gallons of fossil fuels will be consumed. These advancements require ongoing investment to not only develop the technology, but to support its

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deployment broadly across the nation.

Today's cars and trucks are more fuel efficient and cleaner than ever before, and fuel economy improvements continue. Automakers have implemented numerous advancements in conventional gasoline vehicles, including improved engine and transmission efficiency, reduced vehicle weight, improved aerodynamic designs, more efficient cooling and lighting, and other technologies such as stop-start systems to reduce idling. Many of these advancements are outside the combustion process and can greatly improve energy efficiency. There are expected additional opportunities to further reduce greenhouse gas (GHG) emissions and energy consumption, but as manufacturers continue to improve efficiency with increasingly complex technologies, the cost of doing so increases dramatically.

Alternatives to traditional gasoline vehicles, such as plug-in hybrid electric and battery electric vehicles, which get energy from the grid, and fuel cell electric vehicles, which generate energy by converting hydrogen to electricity via a fuel cell, are important and necessary technologies to continue GHG reductions. Global Automakers' members are committed to these technologies and have been investing in the development and deployment of these vehicles for years. Our members are at the forefront, offering alternative fuel vehicles such as the Toyota Mirai Fuel Cell, Honda Clarity Fuel Cell, Hyundai Tucson Fuel Cell, Nissan Leaf Battery Electric, and Kia Soul Battery Electric. Vehicles such as these are known as zero emission vehicles, or ZEVs.

While these advanced technology vehicles offer the possibility of zero emissions travel, they also present many challenges. In order to increase deployment of these technologies, barriers such as cost, refueling infrastructure, market differences, and consumer acceptance must be addressed. The marketplace for these vehicles is still in the earliest stages. Vehicle registration data indicates these vehicles, as a percentage of all new automobiles registered, represented six tenths of one percent (0.6%) of the nation's market in 2015.[1] The new vehicle market share of ZEVs peaked in 2014 at 0.69%, but in

[1] IHS Global Vehicle Registration Data, January-October 2015.

a year of record low gas prices and near record high overall vehicle sales, battery electric, fuel cell electric, and plug-in hybrid electric vehicles did not increase in the market at the same rate as other cars and trucks. Although additional technological advancements are expected for these vehicles—including improved range, reduced costs, and additional model offerings—consumer demand remains low, requiring additional time, resources, and investments by all stakeholders to support market development.

To date, ZEV sales are strongest in states, like California, that commit resources year after year to ZEVs through financial incentives, infrastructure support and consumer awareness, along with other benefits like access to HOV lanes and preferential parking. The results of these efforts demonstrate that introduction of the technology alone is not sufficient to build a market. Instead, there must be a shared responsibility among stakeholders to commit resources to support investments made to date in developing and deploying advanced technologies to ensure such vehicles are adopted at higher rates. We believe advanced vehicle incentives, such as federal consumer tax credit for the purchase of a ZEV vehicle, remain important at this stage.

In addition, long term investments in refueling infrastructure for battery electric, fuel cell electric, and plug-in hybrid electric vehicles are necessary to further promote advanced vehicle adoption and ensure additional GHG reductions. These technologies require their own fueling systems – electric charging stations for battery electric and plug-in electric hybrid vehicles, and hydrogen fueling stations for fuel cell electric vehicles. These technologies cannot succeed without the creation of a robust and vast network of charging and hydrogen stations, and additional support is necessary to help build out this infrastructure. Furthermore, the increased use of renewable fuel sources will provide additional environmental improvements associated with ZEVs.

Automakers are making considerable investments to develop more efficient vehicles to improve fuel efficiency, but as outlined above, challenges remain. As the Environmental Protection Agency, National Highway Traffic Safety Administration and California Air Resources Board assess fuel economy and

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GHG regulations through the 2025 model year, they must assess current technology capabilities, potential capabilities and costs, and market conditions, such as fuel prices and consumer preferences. All these factors play a considerable role in meeting current and future regulations. As fuel economy and GHG regulations become more stringent, it is critical that regulations includes flexibilities, so that automakers can work creatively to improve efficiency and reduce emissions across their fleets.

Looking forward, automakers are developing connected car and automated vehicle innovations that have the potential to revolutionize the entire driving experience, including vehicle energy usage. Automated vehicles, with features available now like Automatic Emergency Braking and Lane-Keeping Assist, help reduce crashes and the associated congestion. Connected car technologies that help reduce crashes and improve traffic management have the potential to make cars dramatically safer and cleaner - saving lives, saving fuel, and saving time spent on the road. Specifically, Dedicated Short Range Communications (DSRC) devices, utilizing the 5.9 GHz spectrum band, allow cars to communicate with each other and with the surrounding infrastructure leading to fewer crashes, less congestion, and other potential benefits. The National Highway Traffic Safety Administration (NHTSA) agrees that this technology could be a "game changer," potentially addressing 80% of vehicle crashes involving non-impaired drivers. With a networked vehicle fleet, there is the potential for achieving even greater GHG reductions and energy savings. We support efforts by the Department of Energy to study the fuel savings associated with crash avoidance and DSRC technologies. Also, to fully realize these immense benefits, the 5.9 GHz band must be protected from harmful interference.

The automobile industry continues to provide innovative technologies with large societal, safety, energy and environmental impacts. The deployment of these technologies across the vehicle fleet takes time, commitment and investment. Ultimately, success requires close collaboration and coordination among government, industry, academia, and other stakeholders. Together, we must work to create markets that value the benefits these technologies offer. Global Automakers and our member companies remain committed to the long-term goal of cleaner and safer vehicles.

Fuel Cell &
Hydrogen Energy
Association

Senate Energy and Natural Resources Committee
Regarding the Status Innovative Technology in the Automobile Industry

Outside Testimony from the Fuel Cell and Hydrogen Energy Association

Summary

Fuel cell electric vehicles (FCEVs) are an exciting new zero-emission transportation option that provides consumers with driving ranges and refueling time found in today's traditional vehicle platforms. These vehicles are not only efficient, but they utilize hydrogen, allowing us to truly diversify our transportation fuel.

Automobile manufacturers have spent billions to bring these vehicles to market to address various federal and state emissions mandates, while providing electric vehicle platforms that exceed consumer expectations.

The efforts have paid off; by the end of 2016 three automobile manufacturers will offer FCEVs for sale or lease in California. Establishing markets beyond California can be accelerated if Congress revisits policies and programs in place designed to speed the adoption of advanced vehicle technologies.

To ensure a successful deployment, we suggest a two-pronged approach that addresses consumer tax credits and a renewed focus by the Department of Energy (DOE) and the Department of Transportation (DOT) on accelerating hydrogen fueling infrastructure.

First, Congress must provide market certainty and parity with other electric vehicles (EVs) and accompanying infrastructure in the tax code. Doing so will help industry replicate the success other advanced vehicle technologies are beginning to enjoy. Furthermore, consumer tax credits based on market penetration will provide an additional level of certainty to the market, and the federal government.

Second, federal agencies like the Department of Energy and Department of Transportation should be directed to increase its support of hydrogen infrastructure and to engage in early market activities that include: **1) improved hydrogen measurement devices for retail stations, 2) durable, low-cost hydrogen compressors, and 3) low-cost carbon fiber tanks.**

Full Testimony

Chairman Murkowski and Ranking Member Cantwell:

On behalf of the members of the Fuel Cell and Hydrogen Energy Association (FCHEA), I am writing to provide an update on the status of the fuel cell electric vehicles (FCEVs) as your committee examines the status of innovative technologies within the automotive industry.

The Fuel Cell and Hydrogen Energy Association is dedicated to the commercialization of fuel cells and hydrogen energy technologies, representing the full global supply chain, including material component and system manufacturers, hydrogen producers and fuel distributors, government laboratories and agencies, trade associations, utilities, and other end users.

Technology

Fuel cell electric vehicles (FCEVs) offer consumers the choice of a zero-emissions electric vehicle without sacrificing the range of a traditional internal combustion engine.

These vehicles, which can be refueled in three-to-five minutes, utilize hydrogen produced from a variety of sources, including natural gas and hydrogen obtained from renewable electrolysis. Additionally, FCEVs are two-to-three times more efficient than traditional internal combustion engine, and when utilizing hydrogen produced from natural gas, significantly reduce emissions on a well-to-wheels basis.

Market

Automotive OEMs have recently begun commercializing fuel cell electric vehicles (FCEVs) in the United States, beginning with markets in California, and are aggressively working to develop markets in the eastern states. As consumers increasingly adopt electric vehicles, it is critical that our industry maintains its positive momentum and continues to educate people around the country on the benefits of FCEV technology.

Hyundai has been leasing its Tucson FCEV crossover in California since June 2014. In October of 2015, Toyota North America began selling and leasing the Mirai FCEV in California as the automaker's vision of the future of electric vehicles. More recently, at the Tokyo Auto Show, Honda unveiled its Clarity Fuel Cell, set to go on sale in the United States and abroad in 2016.

General Motors, Daimler, Nissan, Ford Volkswagen, BMW, and Mercedes Benz have invested significant financial resources in automotive fuel cell technology research and development of several FCEV concepts.

Currently, FCEV deployment is primarily located in California, where the state and private industry are working collaboratively to develop hydrogen fueling infrastructure. The state's Energy Commission has committed $200 million in funding through 2024 to construct and open at least 100 hydrogen fueling stations across the state, with 41 currently planned or under construction in 2016. Toyota has

committed $7.3 million (in loan guarantees) and Honda $13.8 million (in financial assist) to First Element Fuel to further develop hydrogen fueling infrastructure in California.

Beyond California, Toyota recently partnered with industrial gas company Air Liquide to open a network of 12 hydrogen fueling stations in five northeastern states to support FCEV commercialization.

Finally, a coalition of eight states has signed a memorandum of understanding to deploy 3.3 million zero emission vehicles, including FCEVs, by 2025.

Expanded Public Private Collaboration

In 2013, the Department of Energy, in concert with private industry, co-founded H_2USA. This public-private partnership is designed promote the commercial introduction and widespread adoption of hydrogen fueled FCEVs across America by addressing hurdles to establishing hydrogen fueling infrastructure.

Since its inception, H2USA has convened key stakeholder organizations in the automobile industry and fueling infrastructure supply chain to promote awareness and advance commercialization of hydrogen fueling stations nationwide. H_2USAs technical working groups have worked to harmonize codes and standards related to hydrogen storage, transportation, and fueling mechanisms to ensure a uniform and safe customer experience.

Furthermore, H_2USA officials have worked closely with state and regional agencies to develop data-driven roadmaps for the rollout of fuel cell electric vehicles and hydrogen fueling stations in emergent markets such as the northeast.

The automakers' vehicle rollout and station development has also been supported by the work of the National Labs, including the National Renewable Energy Laboratory in Colorado, where station reliability and fuel purity apparatus have been developed to standardize fueling experience across hydrogen stations.

Legislation

Fuel cells and hydrogen are a key component of an *'all of the above'* energy strategy, which recognizes the complexity of energy markets and diversity of our national resources.

We applaud Congress for including a provision in the Highway Bill that instructs the Secretary of Transportation to identify corridors for hydrogen and other alternative fuels.

We were also pleased with the extension of tax incentives for FCEVs and accompanying infrastructure through 2016.

Looking ahead, we ask Congress to provide **certainty and parity with other electric vehicles (EVs) and accompanying infrastructure in the tax code by enacting a multiyear extension of vehicle and infrastructure incentives**. Doing so will help industry replicate the success other advanced technologies

are beginning to enjoy. Furthermore, credits based on market penetration will provide an additional level of certainly to the market, and the government.

We also urge federal agencies, like the Department of Energy and Department of Transportation to **reprogram funding for deployment of hydrogen infrastructure**.

We look forward to continuing our conversation with you and your colleagues as our industry brings cleaner, more efficient vehicles technologies to the marketplace.

Thank you for your consideration.

Bud DeFlaviis

Director of Government Affairs
Fuel Cell and Hydrogen Energy Association

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